

Low Flow Inventory

Summary

In 2002, recognizing the need for deeper examination of streamflow alteration and depletion in Massachusetts, Riverways program staff embarked upon what was called the “Low Flow Inventory”. Staff made contact with people around the state regarding observed and/or measured flow alterations in streams large and small. The resulting Low Flow Inventory brought together existing information into one place to enable individuals, communities, and state agencies to access information and observations about streams with unnatural flow problems and to summarize the extent of streamflow alteration and depletion on a statewide basis. Riverways’ goal was to publicize and educate the public about the extent of the flow alteration and to empower local communities to prevent and restore more natural streamflow patterns and volumes in their rivers.

For many years this information was accessible as a series of linked pages on our website. Over the years, it was less frequently updated, as our staff were focused on stream gaging through our resulting River Instream Flow Stewards (RIFLS) program. Through RIFLS, we work with local organizations to monitor and address specific cases of flow alteration. With our partners and volunteer gage readers, we have been able to more fully document flow stress in some of the streams identified in the Low Flow Inventory (see www.rifls.org).

In recognition that many of the Low Flow Inventory pages were becoming out of date, RIFLS staff moved all of the information from those pages into this single document, accessible on our website. We have not made substantial updates to the content of the pages but have made the following changes:

- Small wording changes, mainly for clarity with reference to the changed format.
- Removed non-functioning links.
- Changed the resources section to be a brief list without web links.

We expect that this document will provide a good snapshot of flow stress in Massachusetts, but we expect that specific streams today may experience different conditions than those described below. Please contact the River Instream Flow Stewards staff with any questions. Our contact information may be found on our website. As of 2013, it is as follows:

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Introduction

Most small streams and many segments of larger rivers are not routinely monitored in the state of Massachusetts for major changes in patterns of streamflow. However, some rivers experience extreme amounts of dewatering, particularly during stressful summer and fall months when streamflow is naturally lowest and human water use is greatest.

Through the *Watershed* links, you can find what information may be available for your watershed and local streams. You'll also find basic information on the *Causes and Effects* of streamflow alteration, a helpful *Glossary* for those pesky terms, and opportunities to find out more through our *Further Research* page. We hope that this information will raise awareness among individuals, communities and state agencies about the extent of the low flow problem; empower local communities to prevent further streamflow reduction; and enable citizens and officials to restore more natural streamflow patterns and volumes in their rivers.

Note, follow the hyperlinks below to reach specific sections.

Watersheds

- | | | |
|---------------------------------|------------------------------------|--|
| • Blackstone | • Merrimack | • South Coastal |
| • Buzzard's Bay | • Millers | • SuAsCo (Sudbury-Assabet-Concord) |
| • Charles | • Narragansett Bay | • Taunton |
| • Chicopee | • Nashua | • Ten Mile |
| • Connecticut | • Neponset | • Westfield |
| • Farmington | • North Coastal | • Weymouth and Weir |
| • Hoosic/Hudson | • Parker | |
| • Ipswich | • Quinebaug | |

Background

[Causes and Effects](#)

[Measurement Methods](#)

[Glossary](#)

[References](#)

Blackstone River Basin

Documented impacted reaches

Dark Brook, Kettle Brook, Mill River, Mumford River, Peters River, Poor Farm Brook, Purgatory Brook, and Tatnuck Brook

Observations

The Blackstone River Basin has smaller amounts of stratified drift and wetlands than many other Massachusetts watersheds. Without significant stratified drift deposits and wetland areas, rainstorms tend to cause flashy rises in streamflow and baseflows tend to be low because there is less water storage capacity available in aquifers. Because of the naturally occurring low summer flows, people living in the watershed have had to find creative ways to store water, particularly for summertime uses. Many impoundments were created historically to store water for water supply, mill operations, and boat passage, particularly during summer months. Between 1828 and 1848, the Blackstone Canal provided passenger and freight passage between Worcester and Providence, but recurring problems with low flows eventually led to its abandonment. There are even reports that during this time mill owners and canal operators sabotaged each other's water control structures during disagreements over the equitable appropriation of streamflow.

Ironically, the Blackstone mainstem may currently have more water in it than ever before. Interbasin transfers of water for the City of Worcester's public water supply come from the Nashua and Chicopee basins and are discharged as wastewater into the Blackstone. In fact, so much of the summer baseflow of the Blackstone is derived from wastewater discharges that there may not be enough clean river water for sufficient dilution of discharged pollutants in some sections.

Despite the flow augmentation from interbasin transfers, many sections of rivers and streams throughout the watershed suffer from unusually low streamflows due to human activities.

Many sources have reported unusual low or no-flow conditions throughout the Blackstone. For example, Poor Farm Brook from City Farm Pond, Shrewsbury, to Lake Quinsigamond was observed dry during November of 1998 by the Blackstone Headwaters Coalition during a shoreline survey. In September of 2004, Department of Environmental Protection (DEP) and Department of Fish and Game (DFG) staff observed no flow conditions in the same location, from City Farm Pond to Lake Quinsigamond (see photos below). The Town of Shrewsbury's Home Farm wellfield is located at the confluence of Poor Farm Brook and Lake Quinsigamond, and is a suspected cause of zero flow conditions. A DEP staff member reported no flow on the Blackstone River below Hovey Pond in North Grafton (6).



Poor Farm Brook between City Farm Pond and Lake Quinsigamond, Shrewsbury, was dry on September 2, 2004.

USGS Water Resource Investigations Report No. 93-4167 states that unnamed headwater tributaries crossing the Quinsigamond Aquifer near one of Shrewsbury's town wellfields lose approximately 0.5 cubic feet per second to groundwater withdrawals and run dry if upstream flow is less than this (1). Local residents too, have noticed changes in streamflow patterns relatively recently. One local resident first noticed low flow problems on the Mumford River in the summer of 1999. These conditions returned in the summers of 2000 and 2001 and some sections of the river even ran dry during these periods (8). The Massachusetts Watershed Initiative funded a study of the causes of low flow incidents on the Mumford River.

Impacts

The causes of low flow in watercourses of the Blackstone are numerous. Although no comprehensive study has been conducted, ground and surface water withdrawals, hydropower generation, dam and reservoir operating procedures, operation of bypass structures, and increases in impervious surfaces related to development are some of the activities most likely to deplete streamflow.

Water Withdrawals

Groundwater withdrawals can have local effects individually and basin-wide effects when considered as a whole. The Massachusetts Water Resources Commission lists the Quinsigamond River as a high stress river based on its low discharge per square mile of watershed compared to other rivers in the state (2). The USGS Water-Resources Report, previously mentioned, also stated that the Auburn aquifer is completely developed and the Quinsigamond aquifer is almost completely developed. This suggests that future growth may lead to further problems with streamflow due to aquifer depletion unless new methods are developed to reduce demand for water.

In fact, DEP's Blackstone River Basin 1998 Water Quality Assessment Report suggests further study of many cases where nearby water withdrawals may already deplete streamflows:

- Streamside wells in the Town of Auburn may affect water levels in Dark Brook.
- The Town of Shrewsbury's well field near Poor Farm Brook may have exacerbated the low water levels that resulted in the brook drying up from City Farm Pond to Lake Quinsigamond in 1998.
- Mill River and Peters River also had low flows which may be the result of nearby groundwater withdrawals.
- In 2004, a DEP staff member observed Purgatory Brook in Sutton dry below Swans Pond with stagnant, non-flowing conditions upstream to the reservoir. Private irrigation wells and development are the suspected causes of declining streamflows in Purgatory Brook. (17)

Dam Management

The Blackstone and its tributaries also have many dams that serve different purposes and may contribute to low flow problems. Some of these dams are not actively managed or are run-of-river, but others are actively managed to produce power or store drinking water, for example. Reservoir operations on Kettle Brook in Leicester and the Holden Reservoir on Tatnuck Brook in Holden may create or exacerbate the low flow conditions that were observed by DEP staff downstream in 1998 (6). Kettle Brook was dry from Reservoir Number 1 in to Waite Pond, Leicester in the summer of 1998. Maintenance and other operations at the Riverdale Mill hydropower facility on the Blackstone in Northbridge and Uxbridge may also contribute to low flow conditions downstream (10). During periods of low flow, water can be withheld and released several times a day, causing fluctuations in river stage, aquatic habitat availability, and navigation downstream. These fluctuations may also help to resuspend contaminated sediments in this reach.

Bypassed Reaches / Diversions

The Synergics Hydropower Project diverts the majority of streamflow in the Blackstone around the Blackstone Gorge to its dam at the old Tupperware Mill in order to generate electricity. In effect, the entire Gorge is bypassed and flow is drastically reduced there. Similarly, flow on the Blackstone essentially bypasses the Town of Worcester because its water supply withdrawals occur on two upstream tributaries, Kettle and Tatnuck Brooks to the northwest, but the discharge point is downstream on the Blackstone mainstem. All the water that would have flowed from Kettle and Tatnuck Brooks through the Blackstone River in Worcester is discharged downstream (11).

Development

One study suggested that an increase in development and imperviousness in the Mumford River subwatershed was at least partially to blame for the increased duration of low flow events in the 1990's. This study noted that low flow events were lower and longer in duration in the 1990's than several decades earlier. In addition to low flow effects, high flows were more frequent, of greater magnitude, and in direct response to storm events, indicating that the flashiness of the river may have increased due to documented increases in development, particularly during the 1980's, in the subwatershed (3).

Consequences

Aquatic Flora and Fauna

DEP conducted a biological assessment of Kettle Brook by comparing it to a reference river which represented the best possible attainable conditions (6). Streamflow on Kettle Brook was affected by

upstream Kettle Brook Reservoir operations which left large areas of substrate exposed. Staff found fewer pollution intolerant macroinvertebrates, such as mayflies, stoneflies, and caddisflies, and more pollution tolerant species, particularly chironomid midges, in Kettle Brook than in the reference river. The fish community was also unbalanced and had a low species richness when compared to the reference site. Although the water quality and aquatic habitat were good enough to support a healthy fish and macroinvertebrate community, low flows on Kettle Brook prevented many aquatic species from occupying all of the available space and thus limited the biological potential of the stream (6). For a stream like this, returning more normal water levels and seasonal variations may be all that is required for the aquatic community to recover and thrive.

Pollution

Low flow conditions themselves create other problems throughout the watershed. In some headwaters of the Blackstone, particularly above the wastewater treatment plant in Hopedale, existing pollution problems become worse during periods of extreme low flow (5). On the Mumford River, one local resident reported seeing juvenile trout with white, “marshmallow-like” growths on their heads, fins, and backs during a period of low flow when the fish were confined to a small pool below the sewage treatment plant (8).

References & Resources

1. Izbicki, John A. 2000. Water Resources of the Blackstone River Basin, Massachusetts. USGS Water-Resources Investigations Report 93-4167.
2. Stressed Basins in Massachusetts. Final draft, Office of Water Resources, version 3. December 2001.
3. Louis Berger Rhode Island, Inc. April 1, 1999. Preliminary Assessment of Causes of Increased Long Duration Low Flow Events in the Blackstone River.
4. Brian Duval, DEP Environmental Analyst, personal communication March 2002.
5. Glen Krevosky, personal communication January 2002.
6. Weinstein, Mollie J., Kennedy, Laurie E. and Jane Colonna-Romano. May 2001. Blackstone River Basin 1998 Water Quality Assessment Report. Commonwealth of Massachusetts Executive Office of Environmental Affairs, Massachusetts Department of Environmental Protection, Bureau of Resource Protection, Division of Watershed Management.
7. Mauri Pelto, Professor of Geology, Nichols College. personal communication January 2002.
8. Mike Yacino, Gun Owner’s Action League. personal communication January 2002.
9. Dan Meharg, National Park Service, Woonsocket, RI. Personal communication with Russ Cohen, MA Riverways Programs.
10. Russ Cohen, Massachusetts Riverways Programs, Department of Fish, Wildlife, and Environmental Law Enforcement. personal communication 2002.
11. [USGS real-time stream gage data for the Blackstone River at Millbury.](#)
12. [USGS real-time stream gage data for the Blackstone River at Northbridge.](#)
13. [USGS real-time stream gage data for the Blackstone River at Woonsocket, RI.](#)
14. [USGS real-time stream gage data for the Quinsigamond River near North Grafton.](#)
15. [USGS real-time stream gage data for the West River below West Hill Dam near Uxbridge.](#)
16. [Blackstone Headwaters Hydrology Project](#), Nichols College
17. Beaudoin, Therese. DEP CERO. personal communication, July 2004.

Buzzard's Bay Basin

Documented impacted reaches

Mattapoisett River and Paskamanset River

Observations

Low flow problems have been noted on both the Mattapoisett and Paskamanset Rivers within the Buzzard's Bay basin. In September 1999, a freshwater mussel surveyor for the Massachusetts Natural Heritage and Endangered Species Program found a series of deep pools with little flow between them on the Mattapoisett River at the Route 6 crossing in Mattapoisett (1). Further upstream, just north of route 195 in Mattapoisett, the river was "bone dry" and local kids were riding their ATV's up and down the streambanks.

Impacts

Water Withdrawals

Several sources indicate that groundwater withdrawals may be the source of low flow events in the Mattapoisett and Paskamanset Rivers. A USGS study of streamflow and groundwater reported that groundwater withdrawals on both the Mattapoisett and Paskamanset Rivers depleted streamflows as compared to upstream sections or other similar nearby streams (2).

Town wells for the towns of Mattapoisett, Fairhaven, and Marion are located close to the segment of the Mattapoisett River that was observed dry in 1999 (1). In addition, the USGS Water Resources Investigation stated that a significant percentage of the baseflow of both the Mattapoisett and the Paskamanset Rivers is pumped out of nearby groundwater wells. Approximately 78% of this water from the Mattapoisett River Basin is then lost from the river when it is discharged as wastewater out of the subbasin through sewage treatment plants in Fairhaven and Marion. Likewise on the Paskamanset River, 100% of pumped groundwater is discharged directly into Buzzard's Bay as wastewater and, again, lost from the river. These groundwater withdrawals have apparently altered the relationship between drainage area and streamflow at least for the Paskamanset River, which was studied in more detail by USGS. Upstream of the wellfield a relationship between drainage area and stream discharge was established. Downstream of the wellfield, discharge was lower than expected according to this relationship, but when the amount of water pumped from the nearby wellfield was added to the actual stream discharge, the relationship was reestablished. These results indicate that the water pumped from the wells was causing an equal amount of induced infiltration from the river (2).

An earlier study by the Department of Environmental Management's Office of Water Resources also found that water withdrawals from the Mattapoisett and, to a lesser extent, the Paskamanset Rivers accounted for a significant portion of base flows. In the Mattapoisett River, 1980-1981 withdrawals equaled 87% of estimated base flow and in the Paskamanset River, withdrawals were 21% of estimated base flows (3).

Consequences

Aquatic Flora and Fauna

During the 1999 low flow episode on the Mattapoisett River, a mussel surveyor observed a few scattered mussel shells of common species and mussel trails in isolated pools (1). Low flows can cause elevated stream temperatures and reduce dissolved oxygen concentrations in isolated pools, forcing

mussels to move in search of better conditions or, like many other aquatic organisms, suffer increased predation risk, severe metabolic stress or even death.

References & Resources

1. Brian Reid, formerly of Wildlands Trust & MA NHESP, personal communication February 2002.
2. Bent, Gardner C. 1995. Streamflow, Ground-Water Recharge and Discharge, and Characteristics of Surficial Deposits in Buzzards Bay Basin, Southeastern Massachusetts. USGS Water-Resources Investigations Report 95-4234.
3. Massachusetts Executive Office of Environmental Affairs, Department of Environmental Management, Office of Water Resources. September 1995. Water Resources of the Buzzard's Bay Watershed: Water Use, Hydrology, and Natural Resources.
4. USGS real-time stream gage data for the Paskamanset River near South Dartmouth.

Charles River Basin

Documented impacted reaches

Beaver Brook, Bogastow Brook, Chicken Brook, Cedar Swamp, Dopping Brook, Fuller Brook, Hopping Brook, Jar Brook, Mill River, Mine Brook, Powisset Brook, Rock Meadow Brook, Stop River, Trout Brook, and Waban Brook.

Observations

Numerous low flow events have been observed across the upper Charles River Watershed. For example, Jar Brook in Holliston was only a few inches deep in August of 1995 and dried completely from late August to early October (3). Cedar Swamp and Weston Pond upstream of Hopping Brook in Holliston were also extremely dry with little to no observable flow through the summer and fall of 1995, a year with below average precipitation (3). Bogastow Brook in Holliston and Millis also ran dry that summer, although Dopping Brook just upstream still had several inches of water (3). In Franklin, Mine Brook flows were too low for DEP staff to sample macroinvertebrates near groundwater withdrawal points (1). Similar low flow conditions precluded sampling on Rock Meadow Brook in Westwood, although staff believed that this may have been a naturally occurring condition because there were no active groundwater wells upstream (1).

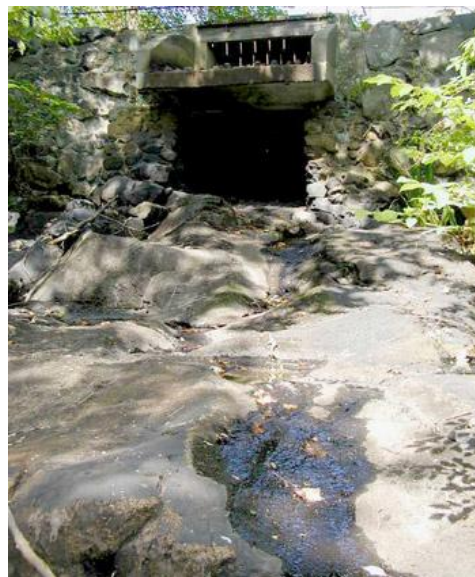
Impacts

Water Withdrawals

Several groundwater wells in the Town of Holliston are suspected to have effects on streamflow levels. The Zone II delineation report for wells numbers 1 through 6 in Holliston states that Bogastow and Hopping Brooks are recharged by groundwater for most of the year, but during drier periods nearby wells may induce infiltration from these streams (4). The Charles River Nonpoint Source Action Plan suggests that Dopping Brook, a tributary of Bogastow Brook in Holliston, should be monitored for impacts from these same groundwater withdrawals by collecting streamflow and benthic macroinvertebrate data (3).

Dam Management

Beaver Brook Reservation on the Belmont/Waltham town line has several water control structures that maintain water levels in Mill Pond and Duck Pond. DEP staff observed that the Beaver Brook streambed was dry from Duck Pond to the lower end of the Reservation during 1995 due to water level management at Duck Pond outlet. This stretch of the Brook has “superb” fish and macroinvertebrate habitat features, but has a moderately impaired benthic macroinvertebrate community because of flow disruptions like the one observed in 1995 (1). The photo here shows the dam at Duck Pond, looking upstream, with no water passing over the spillway on August 15, 2002. A small amount of water can be seen in the photo seeping through the base of the dam, creating the trickle down the streambed.



Bypassed Reaches/Diversions

The Milford Water Company diverts water for public water supply from Echo Lake in Hopkinton. The stretch of the Charles River from Echo Lake downstream to Dilla Street in Milford had excellent habitat for fish and benthic macroinvertebrates when surveyed by DEP staff, but there was little to no flow in this section to support aquatic life (1).

Consequences

Pollution

Low flows may compound the problem of suspected septic system failures on Bogastow Brook in East Holliston. The problem of concentrated pollutants may not only impact aquatic life here, but also the water quality of the community water supply located between Fiske and Central Streets (1).

On Powissett Brook in Westwood and Dover, extremely low flows during summer of 1997 contributed to excessively low dissolved oxygen concentrations and an impaired benthic macroinvertebrate community with few pollution-tolerant organisms. DEP staff suggested that these low flows may have been naturally occurring since there were no known upstream groundwater withdrawals (1).

Aquatic Flora and Fauna

As part of the state's water quality assessments, DEP staff sampled benthic macroinvertebrates at many locations within the watershed. Several of these locations had benthic macroinvertebrate communities that were limited or degraded by low streamflows. For example, along the Charles River from Dilla Street in Milford to the Milford wastewater treatment plant in Holliston, DEP staff observed little to no flow. Aquatic habitat here was limited by the lack of water, and DEP staff found that the resident aquatic community showed signs of degradation. On the Mill River in Norfolk, DEP staff discovered that rheophilic, or flow-loving, macroinvertebrates that were found at the upstream reference site were replaced with slow-water forms in this section of the river. On the Waban Brook in Wellesley, streamflow was below the 7Q10 level on the sampling date in 1997, and water levels were so low that quantitative macroinvertebrate sampling could not be conducted. Qualitative sampling revealed a lack of mayfly and stonefly larvae, two groups of macroinvertebrates that were expected in this reach and are generally intolerant of pollution. Staff suggested that the high water temperature (21.3° C or 70° F), partly a result of low streamflows, may have eliminated them from this stream reach (1).

Current Events (as of 2002)

The Charles River Watershed Association is measuring stream flow in nine tributaries to the Charles River in support of the state's development of Total Maximum Daily Loads (TMDL) for pollutants. The tributaries include: Bogastow Brook, Chicken Brook, Fuller Brook, Hopping Brook, Mill River, Mine Brook, Stop River, Trout Brook, and Waban Brook (5).

References & Resources

1. Fiorentino, John G., Kennedy, Laurie E. and Mollie J. Weinstein. Charles River Watershed 1997/1998 Water Quality Assessment Report, Report Number 72-AC-3, DWM Control Number 16.0. MA DEP Bureau of Resource Protection, Division of Watershed Management.
2. IEP, Inc., Consulting Environmental Scientists. May 20, 1986 . Town of Holliston Brook St. and Central St. Wells. DEQE Chapter 233 Aquifer Land Acquisition Application.

3. Barber, Rosalia, Duval, Brian, and Jeffrey Brownell. Nonpoint Source Action Plan, Charles River Basin . July 5, 2001 . MA DEP.
4. Whitman and Howard, Inc. March 1996. Numerical Groundwater Flow Modeling and Zone II Delineations for Wells No. 1, 2, 3, 4, 5 and 6, Holliston , Massachusetts .
5. "Tracking Tributaries". Streamer, A Publication of the Charles River Watershed Association, vol. 33, No. 2. Summer 2002.
6. [USGS real-time stream gage data for Miscoe Brook near Franklin.](#)
7. [USGS real-time stream gage data for the Charles River at Medway.](#)
8. [USGS real-time stream gage data for the Charles River at Dover.](#)
9. [USGS real-time stream gage data for Mother Brook at Dedham.](#)
10. [USGS real-time stream gage data for Hobbs Brook below Cambridge Reservoir near Kendall Green.](#)
11. [USGS real-time stream gage data for unnamed tributary 1 to Stony Brook near Waltham.](#)
12. [USGS real-time stream gage data for Stony Brook at Rt. 20, Waltham.](#)
13. [USGS real-time stream gage data for Stony Brook Reservoir at dam in Waltham.](#)
14. [USGS real-time stream gage data for the Charles River at Wellesley.](#)
15. [USGS real-time stream gage data for the Charles River at Waltham.](#)
16. [USGS real-time stream gage data for the Muddy River at Brookline.](#)

Chicopee River Basin

Documented impacted reaches

Seven Mile River, Swift River, and Ware River

Observations

There are several indications that some tributaries of the Chicopee River may suffer from stream flow depletion. For example, the USGS stream gage on the Ware River at Barre (#01172500) recorded a minimum stream flow of 0.57 cfs, or 46% of the estimated 7Q10, during the summer of 1999 (2). The Ware River near Barre, Seven Mile River near Spencer, and the East Branch of the Swift River near Hardwick are all listed by the Office of Water Resources as high stress rivers based on their low discharge per square mile of watershed compared to other rivers in the state (1).

Impacts

There is no further information on the rivers classified as high stress rivers, but large withdrawals and interbasin transfers have been noted from the East Branch of the Ware River.

Water Withdrawals

Water withdrawals from the Mare Meadow and Bickford Reservoirs upstream of the East Branch of the Ware River in Westminister and Hubbardston for the Town of Fitchburg's water supply are discharged outside the Chicopee River Basin. Fitchburg is registered to withdraw 2.26 mgd and in 1999 the town withdrew 3.8 mgd from Mare Meadow Reservoir over a 145 day period and 10.4 mgd from Bickford Reservoir over a 31 day period (2).

Dam Management

Because the Town of Fitchburg uses a reservoir system and surface water withdrawals, it is theoretically possible to minimize the impact of water withdrawals on downstream aquatic communities because minimum streamflows can be maintained using stored water. In the 1998 Water Quality Assessment, DEP recommended that Mare Meadow and Bickford Reservoir operations be optimized and other lake outlet control operations be evaluated to mimic as much as possible natural patterns and volumes of stream flow in the East Branch of the Ware River (2).

References & Resources

1. Stressed Basins in Massachusetts. Final draft, OWR version 3. 12/01.
2. Weinstein, Mollie J., Kennedy, Laurie E., and Jane Collona-Romano. April 2001. Chicopee River Basin 1998 Water Quality Assessment Report, Report Number 36-AC-2, DWM Control Number 47.0. MA DEP, Bureau of Resource Protection, Division of Watershed Management.
3. [USGS real-time stream gage data for the Ware River near Barre.](#)
4. [USGS real-time stream gage data for the Ware River at Gibbs Crossing.](#)
5. USGS real-time stream gage data for the Chicopee River at Indian Orchard.
6. [USGS real-time stream gage data for the East Branch Swift River near Hardwick.](#)
7. [USGS real-time stream gage data for the Quaboag River at West Brimfield.](#)

Connecticut River Basin

Impacts

Water Withdrawals

Six public water supplies withdraw water from the Mill River subwatershed upstream of Hatfield. Water withdrawals from reservoirs on West Brook and Roaring Brook within the Mill River subwatershed leave downstream sections of the stream beds dry during low flow periods. The Town of South Deerfield is also under an Administrative Consent Order from the DEP to study the impacts of a possible increase in its permitted withdrawal amount on the river (1). Currently, the New York and Massachusetts Cooperative Research Units are studying instream flow requirements for the Mill River as part of "... a larger effort to develop a simplified method to evaluate instream flow requirements for streams in the Northeast US" (2).

Dam Management

The flow fluctuations on the Connecticut River at the hydropower dam in Holyoke can be seen at the USGS real-time website for the Holyoke stream gage. Rapid daily fluctuations for power generation, often referred to as "hydropeaking", can cause scour, erosion, and downstream sedimentation problems as well as stranding aquatic organisms from eggs to adults in isolated pools or on dry land.

Bypassed Reaches/Diversions

The Connecticut River is diverted at Turner Falls dam into the Northeast Utility's canal and used to generate hydropower. Two miles of the river below Turners Falls dam are bypassed and are virtually dry during low flow periods. During low flow periods, the plant operates as a hydropeaking plant and returns water to the Connecticut River at Cabot Station. During high flows, the plant operates as a base load plant and water is returned to the river over the Montague dam as well. The Federal Energy Regulatory Commission (FERC) requires a continuous minimum flow of 1,433 cfs or an amount equal to the inflow from the river and higher releases are made during the fish migration season (1).

Consequences

Aquatic Flora and Fauna

The dam on the Mill River in Hatfield limits the distribution of state and federally listed freshwater mussels including the alewife floater (*Anondonta implicata*) and triangle floater (*Alasmodonta undulata*). However, it also protects the dwarf wedgemussel (*Alasmodonta heterodon*) from predatory fish that would prey on tessellated darters (*Etheostoma olmstedi*), a species that helps the dwarf wedgemussel reproduce successfully. The Hatfield dam has been rated in poor condition by the Massachusetts Dam Safety group and studies are currently underway to investigate possible alternatives for streamflow management here (1).

Current Events (as of 2002)

The Connecticut River Joint Commissions, a collaboration of citizens and state and federal representatives, produced the Connecticut River Corridor Management Plan in 1997, which includes a Flow Management and Dams section. Suggestions from this collaborative process included: maintaining water flows at levels which will support the full range of its uses and values, coordinating inter-state policies on flow management and water withdrawals, cooperative flow management among tributary

and mainstem dam owners, integrated flow control systems, and sharing of flow management expertise among dam operators (3).

References & Resources

1. Weinstein, Mollie J. and Laurie E. Kennedy. November 2000. Connecticut River Basin 1998 Water Quality Assessment Report, Report Number 34-AC-1, DWM Control Number 45.0. MA DEP, Bureau of Resource Protection, Division of Watershed Management.
2. Cornell University's Instream Habitat Program, Mill River Project Description.
3. [Connecticut River Joint Commissions. May 1997. Connecticut River Corridor Management Plan: Volume 1 Riverwide Overview, Upper Connecticut River in New Hampshire and Vermont.](#)
4. Hanover, Kathy Fallon. April, 1998. Instream Flow Uses, Values & Policies in the Upper Connecticut River Watershed. A report to the Connecticut River Joint Commissions. includes policy and site-specific information and recommendations for the Vermont/New Hampshire section of the Connecticut River .
5. [USGS real-time stream gage on the Connecticut River at Montague City.](#)
6. [USGS real-time stream gage on the Connecticut River below the hydropower dam at Holyoke.](#)
7. [USGS real-time stream gage data for the Mill River at Northampton.](#)

Farmington River Basin

Documented impacted reaches

Fall River, Hubbard River, and Valley Brook

Observations

Hubbard River and Valley Brook near West Farmington, Connecticut are listed by the Office of Water Resources as a high stress river based on its low discharge per square mile of watershed compared to other rivers in the state (1). No further information is available at this time.

Impacts

Dam Management

Lake drawdown in the Otis Reservoir, Otis, has been used to “keep the waterbody in good condition” (free of excessive plant biomass), but one of the negative downstream impacts has been “low spring water level in the Fall River”. It was also noted in the Diagnostic/Feasibility Study by ENSR that rapid lake drawdown may prevent migrations, impair the ability of adjacent wetlands to remove pollutants, and dry up shallow private wells (3).

References & Resources

1. Stressed Basins in Massachusetts . Final draft, OWR version 3. 12/01.
2. [USGS real-time stream gage data for the West Branch Farmington River near New Boston.](#)
3. Farmington River News. April 2002. Newsletter of the Farmington River Watershed Team. “To Drawdown or Not to Drawdown?”

Hoosic/Hudson River Basin

Observations

Very little data exist on stream flow conditions in the Hudson River Watershed in Massachusetts, but a few comments from the 1997 Water Quality Assessment Report indicate that at least a few stream reaches may have low flow problems.

Impacts

Water Withdrawals

Public water supply withdrawals cause an estimated 22% reduction in streamflow on the Hoosic River from the Cheshire Reservoir in Cheshire to the Adams wastewater treatment plant. Streamflow measured by DEP staff in 1997 was always greater than 10 cfs. However, the calculated 7Q10 for this section is 12.63 cfs and DEM recommended a minimum flow threshold of 17.7 cfs for June through August at the [Adams USGS stream flow gage](#) just 0.4 miles downstream (#01331500) (1).

Consequences

Aquatic Flora and Fauna

During DEP's water quality assessment work in 1997, habitat availability at Kinderhook Creek just upstream of its confluence with Bentley Creek was limited due to low water levels, although good substrate and riffle habitats were present (1).

References & Resources

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2. [USGS Hoosic River at Adams stream gage data.](#)
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Housatonic River Basin

Documented impacted reaches

Cady Brook, Cleveland Brook, Furnace Brook, Housatonic River, Karner Brook, Windsor Brook

Observations

Reports of low flow problems in the Housatonic River Watershed include both short and long term disruptions of streamflow. Members of the local watershed team have observed streams suddenly run dry below water supply reservoirs when flow is completely shut off to refill the reservoir (2). In the long term, several diversions deliver water from Cady and Windsor Brooks into the Cleveland Reservoir and leave downstream reaches completely dry. For example, DEP staff observed that the entire flow (22 cfs) of Windsor Brook was diverted to the Cleveland Reservoir, leaving a quarter mile of dry streambed downstream (1). As early as 1939, fisheries biologists noted that the Windsor River could not support coldwater fisheries because flow was reduced to nearly isolated pools during summer (7).

Impacts

Water Withdrawals

The City of Pittsfield used the Cleveland Reservoir for 74% of its public water supply in 1998 by diverting an unquantified amount of water from both Windsor and Cady Brooks. Although a large amount of water is diverted into the Cleveland Reservoir, stream flow in Cleveland Brook itself is more typical of a small first order stream. During DEP's sampling for the 1997/1998 Water Quality Assessment Report, 22 cfs was diverted from Windsor Brook to Cleveland Brook Reservoir, but flows out of the reservoir to Cleveland Brook were only 1.3 cfs (1).

Water withdrawals from Karner Brook in South Egremont exceed the 7Q10 by a factor of 10, although no further information about the impact of these withdrawals is available (8).

Dam Management

Local reports of water control structures throughout the basin holding back all flow were further supported by DEP staff, who observed that one quarter mile of Long Pond Brook was completely dry just below the outlet of Long Pond in Great Barrington during summer of 1992 because no water was released over the control structure (1).

Citizens have also reported flow problems in the Housatonic River below the Glendale Hydropower Project in Glendale, which in some cases meant that no flow passed over the dam for up to 8 hours while the impounded area was refilling (3). These reports prompted a FERC compliance review, which found that both operator actions and equipment deficiencies were to blame for the project's failure to meet the minimum stream flow requirements of its permit. Equipment problems have been resolved and the company now ceases power generation at low flows so that at least a small amount of water passes downstream. DEP's 1997/98 Water Quality Assessment Report recommended that a minimum flow requirement for the bypassed reach be established and incorporated into future permits (1).

Bypassed Reaches/Diversions

Both Cady and Windsor Brooks are diverted through an aqueduct to Cleveland Reservoir. One half mile of Cady Brook and one quarter mile of Windsor Brook upstream of Windsor Reservoir are dewatered or completely dry below this diversion (1).

Consequences

Aquatic Flora and Fauna

The headwaters of Furnace Brook in Richmond to the inlet of Mud Ponds in West Stockbridge had a slightly impaired benthic community relative to the reference site in the 1997/1998 Water Quality Assessment Report. DEP staff suggested that this was due to naturally occurring low flow conditions, but they also recommended an examination of upstream dams and other control structures to evaluate their effects on streamflow (1).

DEM's Office of Water Resources calculated the Aquatic Base Flow (ABF), or mean August streamflow, for many streams and rivers throughout the Housatonic basin. These flow values are intended to assure healthy aquatic ecosystems, based on the principle that the aquatic community has adapted to survive average August low flow conditions. The ABF values ranged from 0.23 cfs to 0.64 cfs across the basin. The following streams were identified as "trout streams", with an Aquatic Baseflow value of 0.27 cfs (9): Umpachene River, Green River; and Karner, Seekonk, Cone, Furnace, Marsh, Beartown, West, Hop, Greenwater, Washington Mt., Felton, Sawmill, Sackett, Wahconah Fall, Cleveland, Bennet, Cady, Lulu, Daniels, Secum, Town, Smith, Jacoby, and May Brooks.

Current Events (as of 2002)

On November 3, 2000, the Old Berkshire Mill Dam on the East Branch of the Housatonic River was removed, the culmination of efforts by the Riverways Programs River Restoration staff, corporate partner Crane and Company and many others. Removal of this dam doubled the amount of habitat available to this coldwater fishery, which includes some of the finest trout seen in the area (4).

References & Resources

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Ipswich River Basin

Documented impacted reaches

Bear Meadow Brook, Boston Brook, Fish Brook, Howlett Brook, Ipswich River, Lubber Brook, Maple Meadow Brook, Martin's Brook, Miles River, Skug River, and Wilmington Brook.

Observations

In 1995, the entire upper half of the Ipswich River ran dry, causing fish kills and other negative impacts (see photo) (7). In 1999, the river ran dry for approximately two miles near the Reading / North Reading town line accompanied, again, by extensive fish kills (4). Numerous other sources have noted low flow conditions in the Ipswich River and its tributaries as well. For example, according to DEP's Nonpoint Source Action Strategy for the Ipswich River Basin, Maple Meadow Brook and Lubber Brook in Burlington and Wilmington Brook and Bear Meadow Brook in Reading and Ipswich all have low flow problems, presumably due to excessive water withdrawals (8).

During data collection for a study of relationships between streamflow and habitat availability (9), USGS staff observed barely perceptible flow velocity at 9 sites, as follows:

- the Ipswich River downstream of Martin's Brook in North Reading.
- the Ipswich River downstream of the South Middleton dam in South Middleton.
- the Ipswich River at Middleton Colony in Middleton.
- the Skug River at Harold Parker Rd. near the Andover / North Andover town line.
- Martin's Brook upstream of Park St. in Wilmington.
- Boston Brook at Peabody St. in Middleton below Curtis Pond.
- Fish Brook downstream of Lost Pond Rd. in Boxford.
- Fish Brook at Lockwood Lane in Boxford.
- Howlett Brook in the wetland reach downstream of Ipswich Rd in Topsfield.

One resident reports that Fish Brook in Boxford has dried completely for the last several years and now dries up for a longer period each summer. This photo shows the Fish Brook dry streambed at Brookview Road in Boxford on September 17, 2002 (17).

The Miles River Task Force was created by conservation officials from Hamilton, Wenham, Ipswich, and Beverly in 2002 to address the problem of low flows in the Miles River. The Salem News reported that "in recent decades, the river has grown shallower, wider and choked with vegetation"(18). The task force intends to address this problem of rapid eutrophication by



examining nutrient inputs from nearby fertilized lawns as well as water withdrawals for golf course irrigation (18).

Impacts

Water Withdrawals

The Ipswich River at South Middleton is listed by the Office of Water Resources as a high stress river based on its low discharge per square mile of watershed compared to other rivers in the state (3). The causes of this low flow have been investigated both on a site-by-site basis and in several watershed-wide studies by the USGS. For example, the results of the pump test for site #1-86 at the 100-Acre Meadow Wellfield in Reading indicated that water from the Ipswich River at least partially recharges the well and reduces water levels in the nearby wetlands (6). The Zone II delineation report for the same wellfield also stated that the river is a primary source of recharge to the wellfield. Furthermore, this study reported that average baseflow during the worst drought year on record was 7 million gallons per day (mgd). The Town of Wilmington exports about 1 mgd of sewage to the MWRA system. The report concluded that "... about 6 mgd is available at the 100-Acre Wellfield during a prolonged drought for induced stream flow infiltration. This value is roughly equal to Reading's maximum daily pumpage" (5).

Basin-wide effects of water withdrawals are described in the USGS Water Resources Investigation Report #00-4029. The report found that withdrawals from groundwater wells in several headwater reaches commonly exceeded stream flow by 50 percent or more, especially during summer months.

Land Use

USGS Water Resources Investigations Report #00-4029 states that in the headwaters of the Ipswich River above South Middleton, 1991 land-use conditions resulted in reduced baseflow to the Ipswich River (1), presumably by reducing infiltration and percolation to groundwater.

Consequences

Aquatic Flora and Fauna

In the Nonpoint Source Action Plan, DEP staff suggested that additional studies be conducted to determine if aquatic habitats have been altered in the lower Ipswich River below the Salem-Beverly Water Supply Canal in Topsfield due to low flow conditions (8).

In addition to multiple fish kills during extreme low flow events, the Ipswich River fish community now consists of 91% habitat generalists, or pond-like species, as opposed to the target community which consists of 28% habitat generalists and 67% fluvial specialists/dependents, or flow-dependent species (11). The Ipswich River Fisheries Restoration Workgroup has come up with minimum flow recommendations for the river based on the results of the USGS habitat assessment report. The Workgroup's draft suggestions for minimum flows to provide enough quality riverine habitat to support a healthy target fish community are (12):

- June to October: 0.49 cubic feet per square mile of watershed area (cfs/m)
- November to February: 1.0 cfs/m
- March to May: 2.5 cfs/m

The Workgroup further recommended that water within the basin be managed so as not to let the river fall below these thresholds. Water restrictions, alternate supplies or other management tools may need

to be implemented before the river reaches the minimum threshold. These measures would provide a buffer to account for delayed effects on the reduction of water levels in the river.

Current Events (as of 2002)

The Ipswich River Watershed Management Council is a group of concerned citizens, water suppliers, environmental activists, and local and state agency personnel that was formed to address water issues in the basin. To date, the Council has been the driving force supporting scientific studies of the issues and is currently working on a draft Ipswich River Watershed Management Plan (14), as well as a regional water conservation plan (for more information, contact the Ipswich River Watershed Association (13)).

References & Resources

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Merrimack River Basin

Documented impacted reaches

Bare Meadow Brook, Cobbler Brook, Martin's Brook, Merrimack River, Spickett River, and Stony Brook

Observations

The Merrimack River Watershed Council and the Groton Lakes Association conducted a shoreline survey of Martin's Pond Brook below the outlet of Martin's Pond in Groton in 1999. From the outlet of the pond to the Route 40 culvert the brook was dry during August and September. Low flow conditions as well as erosion, sedimentation, and turbidity problems were also observed on Bare Meadow Brook from its headwaters in Methuen to its confluence with the Merrimack River. These conditions were attributed to crushed culverts, clogged storm drains, and beaver activity in the area (1).

Impacts

Dam Management

A local resident reported that the operation of the Methuen Falls hydropower project on the Spickett River at Methuen Square repeatedly drained the river dry over the summer of 2002 and affected river flows well into the New Hampshire portion of the Spickett River(4).

Bypassed Reaches / Diversions

At the Lowell Project hydropower facility on the Merrimack River in Lowell, 0.7 miles of river including Pawtucket Falls can be bypassed through a canal system to generate power. The riverbed is periodically exposed when flow is diverted, particularly during naturally low flow periods. In the 1999 Water Quality Assessment Report, DEP recommended establishing minimum flow requirements through the bypassed reach in the next round of permitting (1).

Consequences

Pollution

Reduced baseflow may have contributed to significant deposits of sand and silt on Stony Brook from the outlet of Forge Pond in Westford to its confluence with the Merrimack River (1). As water velocities drop, finer particles are able to settle out of the water column and consequently smother the gravel and boulder habitats that are used by many species of fish and aquatic macroinvertebrates.

Aquatic Flora and Fauna

Low flows limit the amount of habitat available to fish and other aquatic organisms in Cobbler Brook from its headwaters in Merrimac to its confluence with the Merrimack River. DEP staff observed the channel only half full in 1999, leaving the other half inaccessible to water-dependent species (1).

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Millers River Basin

Documented impacted reaches

Priest Brook and Tully River

Observations

The East Branch of the Tully River near Athol and Priest Brook near Winchendon are listed by the Office of Water Resources as high stress rivers based on their low discharge per square mile of watershed compared to other rivers in the state (1). The East Branch of the Tully River was also identified as flow stressed in the Draft Millers River Hydrologic Assessment that was funded by the MA Watershed Initiative. This assessment estimates "virgin" pre-development stream flows and compares them to measured stream flows before and after the construction of the Birch Hill and Tully flood control facilities, which occurred in 1949. The East Branch of the Tully River showed a 33% decline in 95% exceedence flows between "virgin" and regulated flows since 1950, while the pre-1950 estimated flows were similar to "virgin" conditions. In addition, the 7Q10 since 1950 is 75% lower than the estimated "virgin" 7Q10 (2).

References & Resources

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2. Draft Millers River Hydrologic Assessment, 2002. (Watershed Initiative Team Project)

Narragansett Bay Basin

Documented impacted reaches

Palmer River, Rocky Run, and Shad Factory Pond

Impacts

Water Withdrawals

A local resident observed that water levels in Rocky Run, a tributary to the Palmer River in Rehoboth, were depleted by a local contractor who routinely filled his truck with water directly from the river to control dust at construction sites during summer and fall of 2001. The resident stated that the water level in this reach of Rocky Run was noticeably lowered by this activity. In addition to the ongoing drought conditions, this repeated pumping resulted in water levels two to three feet lower than usual for late summer (1).

Interbasin Transfer of Water

The Palmer River from the confluence of the East and West Branches of the Palmer River to Route 6 in Rehoboth suffers from depleted streamflows due to an interbasin transfer of water out of Shad Factory Pond (2). This water is transferred into the Kickemuit Reservoir in Warren, Rhode Island where the Bristol County Water Authority withdraws water for Bristol County, Rhode Island. The Bristol County Water Authority has not metered its withdrawals from Shad Factory Pond, so the actual amount of water removed from the Palmer River Basin is unknown. Additionally, the Bristol County Water Authority has not managed withdrawals and releases from Shad Factory Pond to maintain adequate stream flow to support the aquatic community (see Aquatic Flora and Fauna below) (3).

Consequences

Aquatic Flora and Fauna

Fish passage into and out of Shad Factory Pond is currently impeded by both the dam structure itself and the lack of stream flow. A fish passage structure on the dam has been proposed to allow shad to migrate into and out of the pond, but it is only a feasible alternative if enough water is released over the structure to allow fish to pass. Low flows are likely to be especially problematic on this section of the Palmer River during early fall, when stream flows are naturally lowest and adult shad need sufficient flow to navigate back to the ocean. However, the river could experience low flows at other important times of the year due to water withdrawals or operations of the control structure (3).

References & Resources

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Nashua River Basin

Documented impacted reaches

Asnebumskit River, Boylston Brook, Quinapoxet River, Reedy Meadow Brook, and Trout Brook

Observations

During summer 1998, DEP staff were unable to conduct benthic macroinvertebrate sampling due to low flow conditions in Boylston Brook near Route 70 in Boylston (3). They estimated that these conditions persisted for 2 to 17 weeks (1). The Asnebumskit River in Holden runs dry during low flow periods (4).

Impacts

Water Withdrawals

The installation of the Town of Pepperell's Jersey Street wellfield coincided with nearby Reedy Meadow Brook periodically running dry, although it had always held water previously (2).

Dam Management

No water was released from the Quinapoxet Reservoir in Holden during a DEP field reconnaissance trip in August of 1998. The Quinapoxet River below the reservoir was dry and the first site suitable for benthic macroinvertebrate sampling was 4.5 miles downstream near River Street in Holden. DEP staff recommended optimizing withdrawal practices from the Quinapoxet Reservoir to maintain a minimum flow that mimics the natural flow regime as much as possible in the Quinapoxet River (1).

Interbasin Transfer of Water

The Quinapoxet River also suffered streamflow depletion with the completion of the town sewer (4), which now transports wastewater from the Quinapoxet River to the upper Blackstone River .

Consequences

Aquatic Flora and Fauna

Macroinvertebrate samples from Trout Brook near Manning Street in Holden for the 1998 Water Quality Assessment Report had fewer caddisflies (a pollution-intolerant and frequently flow-sensitive group) and more chironomids (pollution-tolerant and flow-insensitive) than in previous years. The brook was dry on at least four days in August and September 1999, but was still listed as a reference station (1).

References & Resources

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9. [USGS real-time stream gage data for the Nashua River at East Pepperell.](#)

Neponset River Basin

Documented impacted reaches

Beaver Brook, Beaver Meadow Brook, Clay Meadow Brook, Gullivar Brook, Lake Massapoag, Massapoag Brook, Mill Brook, Neponset River, Pequid Brook, Spring Brook, Steep Hill Brook, and Unquity Brook

Observations

Baseflow on the Neponset River at the USGS Norwood gaging station, as estimated from the 7-day annual minimum flow and adjusted for annual daily average flow, has declined significantly since the gage was installed in 1940 (1). A local resident reported that Spring Brook in Walpole has problems with low flows, but no other information is available at this time (7).

Impacts

Water Withdrawals

The Neponset River Watershed Association reports that the interbasin transfers of water out of the watershed exceed 20% of the river's total annual freshwater discharge (2). Water withdrawals have also been noted as a possible factor in low flows which affect smelt spawning in the Neponset River and Gullivar Brook in Milton (6).

Beaver Meadow Brook from Stoughton to Canton is known to have low baseflow problems, as noted by both Neponset River Watershed Association members and Division of Watershed Management staff. Watershed Association members report that local homes and an apartment building pump water directly out of the Brook for lawn and garden watering (6).

The Town of Sharon's municipal groundwater wells near Lake Massapoag may cause low flows in the unnamed tributary that flows from the outlet of Lake Massapoag to the inlet of Hammer Shop Pond (6).

Dam Management

Pequid Brook in Canton has an overall high quality benthic macroinvertebrate community and high species diversity, but the presence of low flow-tolerant species (*Parametriocnemus* sp.) suggests that the brook may experience periodic low flow events. A local resident noted that the brook was dry on August 19, 2002 (8), and the Army Corps of Engineers reported that low flows (less than 10 cubic feet per second) were common in Pequid Brook. The management of several upstream impoundments may affect the frequency and severity of these low flow events (6).

Bypassed Reaches/Diversions

Below Hammer Shop Pond in Sharon, flow in Massapoag Brook is diverted during low flow conditions to Clay Meadow Brook, which drains to Steep Hill Brook and ultimately into Bolivar Pond (6). Unquity Brook in Milton is an urban stream that runs underground for several stretches. Downstream of Milton Cemetery, where Unquity Brook resurfaces, the streambed is completely dry (6).

Consequences

Aquatic Flora and Fauna

Between 1991 and 1994, the Neponset's cold water fishery declined. During low flow events in early summer, smelt spawning habitat is often exposed and the entire season's eggs are desiccated. The photograph here shows the Neponset River just downstream of smelt spawning areas. Temperatures in

the river are also elevated during extreme low flow periods, causing further stress to aquatic communities (2).

The benthic macroinvertebrate community in Mill Brook in Medfield is dominated by chironomid midge larvae, associated with low flow conditions. The fish community includes typical coldwater species that are tolerant of pollution. These two aquatic community characteristics indicate that low flow conditions limit the biological potential of Mill Brook. During field visits for the 1999 water quality assessment, staff observed that only about half of the channel bed was covered with water despite heavy rain the week before (6).

Beaver Brook in Sharon was also home to several species of chironomids tolerant of low flow conditions. The low density of fish in Beaver Brook may be attributable to periodic low flow events. The Boston Harbor 1999 Water Quality Assessment Report suggests that possible sources of reduced baseflow be investigated including the Sharon Water Department's withdrawals (0.55 mgd registered and 0.42 mgd permitted), private water use, and sewer inflow and infiltration (6). This Brook has also been observed to have low flow problems by local residents, who believe that the Brook supports a small but declining population of brook trout, a species that requires cold, flowing water to survive (9).



Human Uses of the River

One business that previously used the Neponset River for cooling water converted to refrigeration because the river is now too warm due to low baseflow and heated runoff from impervious surfaces (2).

Pollution

During low flow events, pollutants become more concentrated and can cause health problems for humans and aquatic organisms. Recreational activities may be restricted and aquatic organisms may become trapped in ever-shrinking pools with pollutants that become toxic when concentrated (2).

References & Resources

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North Coastal Basin

Documented impacted reaches

Alewife Brook (Essex), Alewife Brook (Gloucester/Rockport), Beaverdam Brook, Cat Brook, Goldthwaite Brook, Hop Brook, Proctor Brook, and Saugus River.

Observations

Members of the Saugus River Watershed Association and others are concerned about low flow problems in the Saugus River from its headwaters to the tidal area near the Saugus Iron Works in Saugus. The section of river downstream of the Lynn Water and Sewer Commission dam is particularly affected although the operation of the dam is perceived as only part of the problem (2). For example, the Saugus River from Lake Quannapowitt in Wakefield to the Lynn Water and Sewer Commission's diversion canal in Lynnfield suffers from low flow problems. DEP staff measured extremely low discharge at the outlet of Lake Quannapowitt in June and July of 1997 (0.05 and 0.02 cfs, respectively).

Likewise, DEM staff measured low discharge in the Lynn Water and Sewer Commission's Diversion canal in July, September, and October of 1997 (0.17, 0.13, and 0.07 cfs, respectively). These low flows in the Saugus River were accompanied by low dissolved oxygen concentrations of 2.3 and 2.9 mg/l, or 25% and 33% saturation (1). These values are below the criteria for Class B waters.

The upper reaches of the Saugus River were particularly hard hit by the 2002 drought. In that year, the Saugus River Watershed Council measured their lowest dissolved oxygen concentrations since 1991 when their program began. Less than 1 mg/L of dissolved oxygen was measured at some locations, well below the Class B standard of 5 mg/L. Low flows also caused the river to recede until it was a series of isolated pools in the upper reaches. Without flowing water, the dissolved oxygen levels in these pools plummeted and resulted in fish kills of species including sunfish, largemouth bass, and yellow perch (9).

Low flow problems have also been documented in several other streams in the North Coastal Watershed. Beaverdam Brook in Lynnfield suffered from low flows (less than 0.1 cfs) and low dissolved oxygen concentrations between June and September of 1997 (1). At Goldthwaite Brook in Peabody in 1997, DEP staff observed a dry stream bed and guessed that a blockage under the bridge could be one cause, although the impacts of several water withdrawals in the area should also be evaluated (1). USGS and DEP measured stream flow in Proctor Brook in Peabody during 1997 and 1998 and found very low flows between July and November of 1997 (1).

Impacts

Water Withdrawals

The Office of Water Resources listed Hop Brook near Salem as a "high stress" river based on its low discharge per square mile of watershed compared to other rivers in the state (7).

Alewife Brook in Essex has several nearby water withdrawals that may have caused periodic low flow events including the Town of Manchester's Round Pond Wells #1 and #2, Gravelly Pond surface water withdrawal in Hamilton, the Town of Essex's Centennial Grove Wells #1 and #2, and Harry Homan Well #1 in Essex. Centennial Grove Wells #1 and #2 and the Harry Homan Well #1 have a combined yield of 200,000 gallons per day, but during peak withdrawals periods this amount can triple. This means that

during the summer when stream flow is naturally lowest up to three times as much water can be withdrawn from these wells to meet summer water demands such as lawn watering and car washing.

Several sources have noted the probable connection between these groundwater withdrawals and stream depletion. During the pump test for the Centennial Grove well the temperature of water being pumped increased about two degrees and this increase was attributed to the influence of warmer surface water being drawn into the well (4). The Conceptual Zone II Delineation report for the Centennial grove and Harry Homan's wells also supported the theory that streamflow in Alewife Brook may be affected by these wells. Relatively high aquifer transmissivity values and a quick stabilization and recovery during the pump tests indicated that there was a significant amount of induced infiltration from Alewife Brook and the surrounding wetlands. The direction of groundwater flow from nearby hills toward Alewife Brook and Chebacco Lake also indicates that these wells located near Alewife Brook probably intercept groundwater flow to the brook (6).

Dam Management

DEP staff observed stagnant water and no flow to the unnamed tributary below the outlet of Babson Reservoir in Gloucester (1,2). This section is downstream of the public water supply intake at Babson Reservoir as well as Alewife Brook, where low flows were also observed (see *Consequences: Aquatic Flora and Fauna*). Below are photos of the nearly dry streambed in Alewife Brook at Pond Street in Essex (left) and the flashboard under Apple St. in Essex with no water flowing over it (right, looking upstream) taken on August 15, 2002.



Bypassed Reaches / Diversions

A study of low flows and habitat availability for fish and macroinvertebrates on the Saugus River, funded by the Massachusetts Watershed Initiative Program, found that current streamflow patterns are most reduced compared to historic patterns in the summer and during certain periods of the fall and spring when water suppliers refill their storage reservoirs. The historic alewife run is no longer thriving, but recommendations for minimum flow releases from the Lynn Water and Sewer Commission's diversion were made to provide stream flow, habitat, and forage to increase the population. The following minimum flow recommendations were based on a combination of fish and macroinvertebrate habitat needs and water supply needs: 3 cfs from June 1 to September 30, 6 cfs from October 1 to February 28, 12 cfs from March 1 to April 30, and 10 cfs from May 1 to May 31.

Consequences

Aquatic Flora and Fauna

In July 1997 DEP staff observed low flow and low dissolved oxygen concentrations (1.9 mg/L, 20% saturation) in Alewife Brook in Gloucester and Rockport (not to be confused with Alewife Brook in Essex). This stream is classified as Class A, or public water supply source, which means that dissolved oxygen levels should be at least 6.0 mg/L or 75% saturation to support aquatic life and public water supply uses. This section of Alewife Brook had also been chosen as a reference site for benthic macroinvertebrate biomonitoring because of its excellent habitat characteristics including riffles, rocky substrates, and an intact riparian zone. However, one month after identifying this as a reference site, staff were unable to sample this section of Alewife Brook because there was no flowing water (1).

Another low dissolved oxygen concentration (4.8 mg/l, 42% saturation) was measured on Cat Brook near School Street in Manchester and attributed to low flow conditions (0.05 cfs in October of 1997). Although the streamflow and dissolved oxygen concentration was poor at this site, the benthic macroinvertebrate community was diverse and included members of nine families of organisms (1).

References & Resources

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2. Joan Leblanc, Saugus River Watershed Council. Personal communication, March 2002.
3. Gomez and Sullivan Engineers and MA DEM. June 2002. Impacts on Streamflows in the Saugus River from Human Manipulation, Final Report.
4. Cohen, Russ . August 16, 1994 . Memo to John Phillips, Commissioner.
5. Barber, Rosalia. May 4, 2001 . Nonpoint Source Action Strategy, North Coastal River Basin. MA DEP.
6. Earth Tech, Inc. June 2001. Final Report, Source Water Assessment Program Conceptual Zone II Delineation Harry Homan's Gravel-Packed Wells #1 and #2 and Centennial Grove Gravel Packed Well, Essex Water Department. Essex , MA . Prepared for Massachusetts Department of Environmental Protection.
7. Stressed Basins in Massachusetts . Final draft, OWR version 3. 12/01.
8. USGS real-time stream gage data for the Saugus River at Saugus Iron Works, Saugus.
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Parker River Basin

Documented impacted reaches

Bachelder Brook, Bull Brook, Dow Brook, Egypt River, Mill River, and Parker River

Observations

The [Parker River USGS stream gage at Byfield](#) has recorded a declining trend in streamflow in the river within the last decade and is considered a high stress river based on its low discharge per square mile of watershed (cfs/mi) compared to other rivers in the state (2). Other streams that are reported to have low flow problems within the basin include the Egypt River downstream of Bull Brook and Dow Brook Reservoirs and Bachelder Brook in Rowley (1). In addition, the reach of the Parker River between the Georgetown wells and Rock Pond was observed to have little or no flow in 1999 (3).

Impacts

Water Withdrawals

In 1999, the Ipswich Water Department withdrew 0.26 mgd over their registered volume from the Parker River watershed. They have since applied for an increase to their registered volume of 0.64 mgd.

Consequences

Aquatic Flora and Fauna

The Mill River (right) in Boxford and Rowley was observed by DEP staff with only 50% of its channel inundated in summer of 1999. The other 50% of the channel was unavailable as habitat for fish and other aquatic organisms. The Water Quality Assessment Report also noted inadequate fish passage in the Mill River (3).



Current Events (as of 2002)

The Massachusetts Watershed Initiative has funded a study that began in 2002 to investigate possible causes of declining streamflow in the Parker River. Some possibilities that will be explored are water withdrawals from the Georgetown wellfield, the Town of Byfield's bedrock and overburden wells, beaver activity, new water users, and renovations to the Pentucket dam.

References & Resources

1. Rich Tomczyk, Ipswich/Parker Watershed Initiative Team Leader. Personal communication, February 2002.
2. Stressed Basins in Massachusetts . Final Draft, OWR version 3.12. 12/01.
3. Weinstein, Mollie J. and Susan G. Connors. August 2001. Parker River Watershed Water Quality Assessment Report, Report Number 91-AC-1, DWM Control Number 54.0. MA DEP, Bureau of Resource Protection, Division of Watershed Management.
4. [USGS Parker River stream discharge gage at Byfield](#)

Quinebaug River Basin

Impacts

Dam Management

Hatchet Brook in Southbridge has been reported to have low flow problems when the upstream reservoir holds back water (1).

References & Resources

1. Pelto, Mauri. Nichols College. Personal communication, February 24, 2004.

South Coastal Basin

Documented impacted reaches

Herring Brook, Jones River, Third Herring Brook (Hanover and Norwell), Third Herring Brook (Pembroke), Town Brook, Tubbs Meadow Brook, and Wildcat Brook

Impacts

Water Withdrawals

Several sources have noted that Third Herring Brook in Hanover and Norwell (not to be confused with Third Herring Brook in Pembroke) is severely depleted by nearby public water supply wells for the Town of Hanover. The Water Commissioner for the Town of Norwell reported that a several-hundred-foot stretch of river below the town wells for Hanover and Norwell near Pond Street in Hanover and South Street in Norwell has repeatedly run dry (4). The Zone II Delineation report for the Old Pond Meadows Aquifer in Hanover and Norwell reported streamflow of 0.2 to 0.5 cfs in June and July of 1995. It also reported a loss of 0.54 cfs to 0.60 cfs between points on the river upstream and downstream of the water supply wells. Furthermore, in July 1995, 0.08 cfs were measured flowing past the upstream station and the stream just downstream was completely dry. By mid-August the upstream station was also reduced to a mere trickle of water and the downstream station was still dry (3). The pump test for the proposed Norwell Well #11 near the confluence of Third Herring and Wildcat Brooks indicated that a confining layer of peat below the Wildcat Brook would prevent any significant stream flow impacts, although the water level in Wildcat Brook was lowered slightly at the nearby measuring point (3).

Bypassed Reaches / Diversions

The diversion of water from Furnace Pond in Pembroke to Tubbs Meadow Brook in Pembroke as part of the City of Brockton's water supply management scheme frequently leaves stream flow in Herring Brook, the pond's natural outlet, depleted (and often completely absent) (1).

Consequences

Aquatic Flora and Fauna

The Jones River in Kingston flows out of Silver Lake, which is used by the City of Brockton for much of its water supply. Due to management of lake levels, flow to the Jones River is frequently non-existent and the headwaters virtually dry up. As a result, there are no permanent aquatic communities remaining in the headwater reaches and large mussel kills, particularly of juveniles, are not uncommon along the shoreline of the lake (2). The lake harbors a diverse mussel assemblage for this area and is one of the few remaining locations of two listed freshwater mussel species, the Eastern Pondmussel (*Ligumia nasuta*) and the Tidewater Mucket (*Leptodea ochracea*) (2). During a site visit by Riverways and Jones River Watershed Association staff in February of 2002, water was flowing backwards, up the Jones River into Silver Lake because Forge Pond dam just downstream on the Jones River had backed up water, partially from groundwater seeps, which could then flow backward into Silver Lake while the lake level was low. Below the Forge Pond dam, the headwaters of the river were just a trickle of stormwater runoff and an accompanying rusty orange deposit on the streambed (1).

Current Events (as of 2002)

The Town Brook dam in Plymouth was removed in September 2002 and is the second of two pilot dam removal projects undertaken by the Riverways Program's River Restore and its collaborators. In

conjunction with a new fishway downstream, this dam removal will allow herring access to migration routes and spawning sites upstream for the first time in at least 300 years (5).

References & Resources

1. Pine DuBois. Jones River Watershed Association. Personal communication with Margaret Kearns, MA Riverways Program, February 2002.
2. Brian Reid. Email to Margaret Kearns, MA Riverways Programs. February 16, 2002.
3. Reed, Donald E. August 1995. Zone II Delineation, Old Pond Meadows Aquifer, Towns of Hanover and Norwell.
4. Steve Ivas. Water Commissioner, Town of Norwell. Personal communication with Russ Cohen, MA Riverways Program, 2002.
5. [Massachusetts Riverways Program River Restore webpage.](#)
6. [USGS real-time stream gage data for the Jones River at Kingston.](#)

Taunton River Basin

Documented impacted reaches

Canoe River, Fall Brook, Muddy Cove Brook, Nemasket River, Poor Meadow Brook, Queset Brook, Robbins Pond Outlet, Rumford River, Sally Richmond Brook, Segreganset River, Stump Brook, Trout Brook, and Wading River

Observations

The Nemasket River headwaters in Middleborough dried in 1997 (3). The Segreganset River near Dighton and the Wading River at Mansfield are in DEM's high stress category based on their low discharge per square mile of watershed (cfs/m) compared to other rivers in the state (1).

Impacts

Several streams in the Taunton River watershed were identified in the [USGS Water Resources Investigations Report #99-4006](#) as sites where "...streamflow statistics could not be estimated... because flow regulations, water withdrawals, or diversions caused poor correlation between the measured flow for the LFPR [low flow partial record] station and daily mean flows for nearby gaging stations" (Ries, 1999; p. 9). These included Trout Brook at Brockton, Poor Meadow Brook at South Hanson, Robbins Pond Outlet near East Bridgewater, Queset Brook at North Easton, and Rumford River at East Foxboro.

Although the reasons for the lack of correlation with nearby streams were not explored further, these sites deserve further investigation for streamflow and low flow issues. While many of the nearby gaging stations also have water withdrawals and/or dams on them, they still have a more natural stream flow regime (4).

Water Withdrawals

Several observers have noted that the Canoe River below the Newlands Street bridge in Norton has severe low flow problems near the Town of Norton's Well #3 (see *Consequences: Aquatic Flora and Fauna*, below) (2).

Stump Brook in Halifax also has recurring low flow problems due to the diversion of water from Monponsett Pond, Stump Brook's source, to Silver Lake in Kingston, which supplies the City of Brockton with drinking water. No flow was visible in Stump Brook during a field visit on February 26, 2002 when water was being diverted from Monponsett Pond to Silver Lake (7).

Consequences

Aquatic Flora and Fauna

Severely reduced stream flow on the Canoe River in Norton resulted in extremely warm water and freshwater mussel kills near the Norton Town Well downstream of the Newlands Street bridge. Observers noted dead mussels and many mussel tracks indicating that the mussels were stressed by the low flow and high temperature conditions, although the streambed substrate appeared to be good habitat for mussels if streamflow were adequate (2). This site has in the past harbored several listed freshwater mussel species including the Triangle Floater (*Alasmodonta undulata*), Eastern Pondmussel (*Ligumia nasuta*), and Dwarf Wedgemussel (*Alasmodonta heterodon*) (3). About 100 yards downstream from this site, the stream flow increased again and the water temperature cooled, indicating that baseflow or groundwater recharge of the stream was occurring (2).

While surveying for anadromous fishes in the Taunton River watershed, staff from the Division of Marine Fisheries observed a surprising number of tributaries dry for unknown reasons during the summer of 2002 (8): Muddy Cove Brook at Hart St. in Dighton, Fall Brook at Glebe St. in Taunton, Sally Richmond Brook at Main St. in Dighton, and an unnamed tributary of the Taunton River at Hill St. in Raynham. Obviously, none of these streams was providing habitat for its native, resident, or anadromous fish population.

References & Resources

1. Stressed Basins in Massachusetts. Final draft, OWR version 3. 12/01.
2. Pat Huckery. MA Natural Heritage and Endangered Species Program. Personal communication, March 2002.
3. Brian Reid. Personal communication, February 2002.
4. [Ries, Kernell G. 1999. Streamflow Measurements, Basin Characteristics, and Streamflow Statistics for Low-Flow Partial-Record Stations Operated in Massachusetts from 1989 Through 1996. Water Resources Investigation Report 99-4006.](#)
5. [USGS real-time stream gage data for the Taunton River near Bridgewater.](#)
6. [USGS real-time stream gage data for the Wading River near Norton.](#)
7. Kearns, Margaret. MA Riverways Programs. Site visit with the Jones River Watershed Association, February 26, 2002.
8. Fish sampling data received from Steve Hurley, MA Division of Marine Fisheries, June 3, 2004.

Ten Mile River Basin

Documented impacted reaches

Coles Brook, Four Mile Brook, Scott's Brook, Seven Mile River, and Ten Mile River

Observations

During fall of 2001, both DEP staff and members of the Wheaton Stream Team discovered that Scott's Brook in North Attleboro and Plainville was dry (1, 2). Possible causes may be upstream golf course water withdrawals, or a number of small ponds upstream (1).

Impacts

Water Withdrawals

Water withdrawals in the headwater of Coles Brook in Rehoboth and Seekonk may contribute to low flow events, such as those observed by DEP staff in summer of 1997 (1) and Riverways staff in August of 2002 (2). The Town is currently considering re-opening two wells nearby, which could further exacerbate the problem (2).

Consequences

Aquatic Flora and Fauna

The Ten Mile River in Plainville and North Attleborough was assessed by DEP staff as having good to excellent fish habitat, but only four fish were collected during routine sampling in 1997. The suspected cause of the "marginal" fish community is flow management activities just upstream at Falls Pond (1).

The Sevenmile River in North Attleborough also had low numbers of fish and a lack of true stream species although excellent habitat existed. Stream flow management at the Hoppin Hill Reservoir is the suspected cause of these problems (1).

The benthic macroinvertebrate community in Fourmile Brook in Attleboro could not be quantitatively sampled in 1997 due to low streamflow. This section received the lowest habitat assessment of all of DEP's biomonitoring stations in this study due to riparian zone removal, road and lawn runoff, and extremely low base flow. Possible causes of low streamflow were flow releases from the dam at the Manchester Pond Reservoir upstream or naturally occurring low flow (1).

References & Resources

1. Kennedy, Laurie E., Maietta, and John F. Fiorentino. March 2000. Ten Mile River Basin 1997 Water Quality Assessment Report, Report Number 52-AC-1, DWM Control Number 18.0. MA DEP, Bureau of Resource Protection, Division of Watershed Management.
2. Rachel Calabro, MA Riverways Programs' Adopt-A-Stream Coordinator. Personal communication with Margaret Kearns, 2002.

SuAsCo (Sudbury-Assabet-Concord) River Basin

Documented impacted reaches

Assabet River, Cold Harbor Brook, Concord River, Elizabeth River, Fort Meadow Brook, Howard Brook, Jackstraw Brook, Nashoba Brook, Sudbury River, and Taylor Brook.

Observations

The Sudbury River ran dry for about 200 feet near Fruit Street in Hopkinton during August - September 1999 for about 15 days (photo below) (1). In the Assabet River subwatershed, Nashoba Brook near Acton is listed by DEM as a high stress basin based on its low discharge per square mile of watershed compared to other rivers in the state (2).

Impacts

Water Withdrawals

The no-flow event on the Sudbury River near Fruit Street in Hopkinton may have been due to a combination of 1999 drought conditions and numerous groundwater wells nearby. All of the Town of Hopkinton's wells plus the wells for a golf course are located near the Fruit Street section of the Sudbury River. The Town of Westborough has installed a monitoring well at Fruit Street to observe future water levels (1).

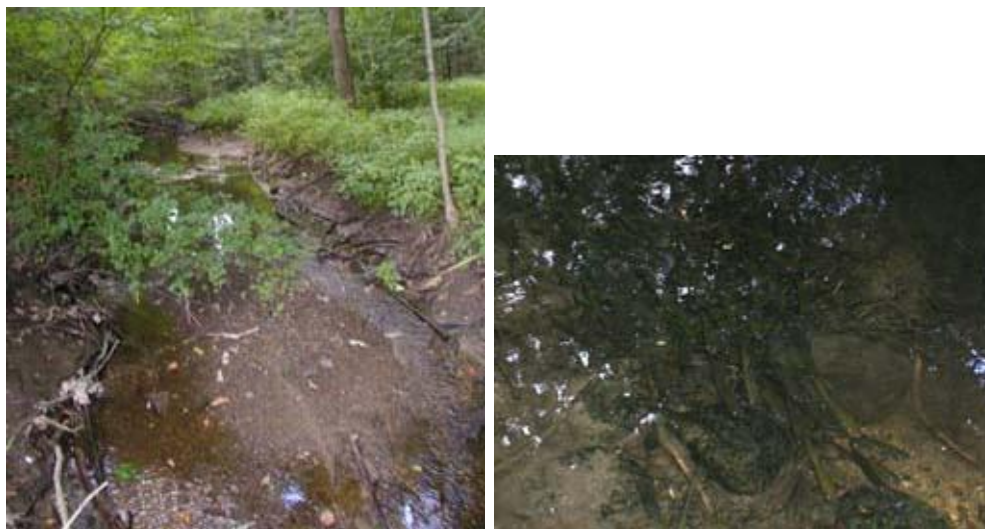
The Organization for the Assabet River (OAR) is concerned that the operation of the Howard Street wells in Northborough is depleting stream flow in Howard Brook and possibly impacting the trout fishery there (6). A vernal pool site near a well field in Acton was also nearly dry in early spring of 2002, a time when this pool has been about five feet deep in the past (4).



Elizabeth Brook, a tributary of the Assabet River in Stowe, Boxborough, and Harvard, was too low for water quality sampling during 1999. Members of OAR, among others, worry that streamflow in many tributaries of the Assabet suffer from frequent low flow problems. A comparison of withdrawals versus the amount of water in the tributaries during low flow periods indicates many stream sections where water withdrawals exceeded the estimated 7Q10: approximately 140% of the estimated 7Q10 is withdrawn from the A1 impoundment's subwatershed in Westborough, approximately 85% of the estimated 7Q10 is withdrawn from the Howard/Cold Harbor Brook subwatershed in Northborough, approximately 440% of the estimated 7Q10 is withdrawn from the Fort Meadow Brook subwatershed in Hudson, approximately 450% of the estimated 7Q10 is withdrawn from the Millham Reservoir subwatershed in Marlborough, and approximately 140% of the estimated 7Q10 is withdrawn from the Taylor Brook subwatershed in Maynard (5). OAR recently received an EPA EMPACT grant to study the effects of surface water withdrawals on stream flow in several of these tributaries (3).

Jackstraw Brook in Westborough was observed dry between Westborough's water supply wells on August 12, 2004. Several isolated pools near Upton Road were the last refuge for native brook trout (see photo below), whose presence indicates that this brook was once a high quality cold water fishery. Low

flows and heavy sediment loads from upstream development have degraded habitat for aquatic species, and the trout have to congregate in the few remaining pools for survival (11).



Low flows and heavy sediment loads from upstream development degrade habitat for coldwater fisheries in Jackstraw Brook, Westborough (left). Native brook trout survive in isolated pools along Jackstraw Brook (right). September 2, 2004.

Dam Management

The Assabet River below the A1 impoundment (also known as Mill Pond) in Westborough runs dry for a length of about 1 mile during dry periods (3, 5). When the structure was built for flood control purposes in the 1950's, there may have been a minimum flow release requirement of 3.5 cfs, but, partly because the impoundment is shallow and does not have much storage capacity to allow releases to improve stream flow, this minimum flow requirement has not been met. Further downstream, seven wastewater treatment plants discharge to the river and actually increase stream flow during dry periods above naturally occurring levels (3). The lowest seven-day average flow (7Q10) at the USGS gaging station in Maynard was 11.6 cfs in August of 1999. During this same month the average wastewater effluent discharge upstream was 12.6 cfs (5). Thus, the wastewater effluent constituted essentially the entire flow of the river at Maynard and was not diluted or augmented by any base flow in the river. This phenomenon of increased discharge during low flow periods due to wastewater effluent can be observed by noting the frequency and magnitude of low flow events on the USGS Water Resources webpage for historic stream flow data at the [Maynard USGS gaging station \(station #01097000\)](#).

References & Resources

1. Linda Hubley. SWAMP. Personal communication with Margaret Kearns, February 2002.
2. Stressed Basins in Massachusetts. Final draft, OWR version 3. 12/01.
3. Sue Beede, Organization for the Assabet River. Personal communication with Margaret Kearns, February 2002.
4. Shep Evans. Personal communication with Margaret Kearns, March 2002.

5. Ronald Manfredonia, Associate Director of Surface Water Programs, Environmental Protection Agency, New England Region. December 8, 2000. Comments on the Environmental Notification Form for the Assabet River Consortium's Wastewater Management Plan (EOEA file #12348).
6. Organization for the Assabet River. June 2000. Summary of OAR's Work on Flow Issues, September – present (6/00).
7. [USGS historic discharge data for the Assabet River at Maynard](#)
8. [USGS real-time stream gage data for the Assabet River at Maynard.](#)
9. [USGS real-time stream gage data for the Sudbury River at Saxonville.](#)
10. [USGS real-time stream gage data for the Concord River below R Meadow brook, Lowell.](#)
11. Richards, Todd . MA Division of Fisheries and Wildlife. Personal communication with Margaret Kearns, August 12, 2004.

Westfield River Basin

Documented impacted reaches

Little River

Observations

DEP's Nonpoint Source Action Strategy mentions that the section of the Little River from the outlet of Cobble Mountain Reservoir in Russell to the impoundment at Horton's Bridge, Westfield, experiences severe hydrologic alteration from reservoir management and water withdrawals. The document recommends that this section be placed on the 303(d) list of impaired waters and that the hydrologic impact of the reservoir be documented so that alternative strategies can be recommended to reduce negative impacts in the river downstream (1).

In addition, the hydropower plant on the Little River periodically shuts down when flows are too low to generate power and completely stops the flow of water downstream. At other times, the dam hydropeaks and streamflow can skyrocket, again leaving little habitat suitable for native aquatic species (2).

References

1. Miller, Tracey. July 6, 2001. Nonpoint Source Action Strategy, Westfield River Basin. MA DEP.
2. Tom Christopher. Personal communication with Margaret Kearns, March 1, 2002.

Weymouth and Weir River Basins

Documented impacted reaches

Accord Brook, Crooked Meadow Brook, Plymouth River, Town Brook, and Weir River

Observations

Estimated pre-development baseflows for the Plymouth River in Hingham indicate that the river would run dry in September and October during dry years, but would flow year-round with normal or above average precipitation (2).

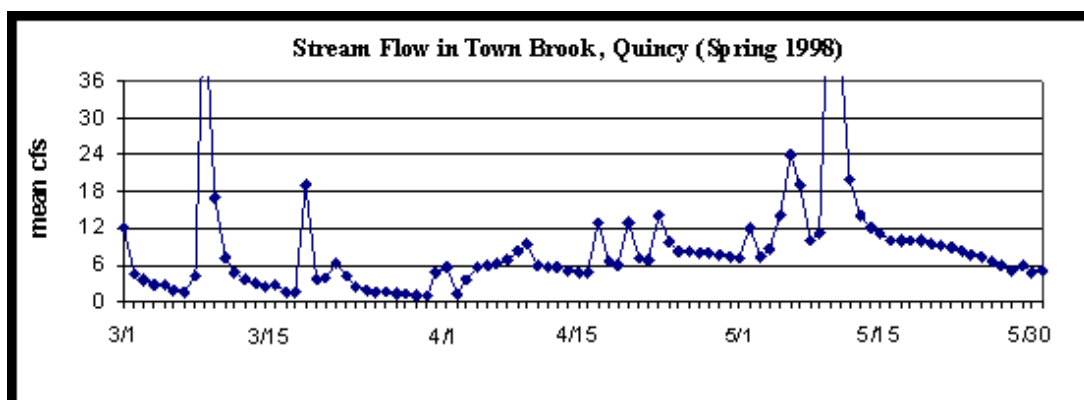
Impacts

Bypassed Reaches / diversions

The section of Accord Brook with the worst low flow problems is in Wompatuck State Park in Hingham. In this reach, water is diverted out of the streambed to recharge public water supply wells. This bypassed reach was dry from June to October in 1999 (3).

A unique bypass problem occurs as a result of the US Army Corps of Engineers' "deep rock tunnel" from Town Brook in Quincy to the Atlantic Ocean (top photo, March 1998). The tunnel was created to alleviate flooding problems downstream, but also siphons away baseflows, causing chronic low flows over smelt-spawning habitat. These conditions have resulted in significant smelt egg kills and spawning habitat degradation over the last five years (bottom photo, March 1998).

In addition to the dewatering caused by the deep rock tunnel, Town Brook also experiences frequent streamflow spikes, which cause additional stress to the aquatic community (4) (see hydrograph below).



Consequences

Aquatic Flora and Fauna

Low flow problems in the Weir River and Accord Brook, one of its tributaries, were identified in the Weir River study. Pre-development stream flow for August was estimated to be 0.68 cfs, but conditions in Accord Brook were 0.37 cfs and in the Weir River 0.39 cfs during the study. Baseflow was reduced by up to 62% in the Weir River, and Accord Brook currently dries completely.

The Weir River report developed minimum streamflow recommendations to satisfy human demands and maintain adequate habitat for selected river fish in the Weir River:

- 0.14 cfs for June through October
- 1.07 cfs for October through March
- 3.11 cfs for March through May
- 1.36 cfs for May through June.

Maintaining these minimum flows in the river would provide just 50% of the fish habitat that was available during low flow periods under “virgin” pre-development conditions. The study also estimated that in order to maintain these seasonal minimum flows, a maximum of 2.7 mgd could be withdrawn from the Weir River Basin, as compared to the current 4.28 mgd that is withdrawn (4). DEP staff compared benthic macroinvertebrate communities in Crooked Meadow Brook, Hingham, and Accord Brook, Hingham. Although Crooked Meadow Brook was estimated to run dry even under pre-developed conditions in the Weir River Report, its benthic macroinvertebrate community was composed of typical flowing water species. Accord Brook, on the other hand, was also inhabited by organisms typically associated with stagnant water and temporary streams (1).

References & Resources

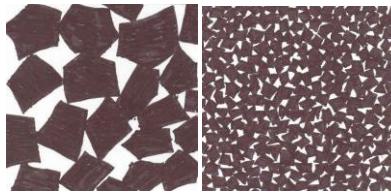
1. Boston Harbor Basin 1999 Draft Water Quality Assessment Report. (Revised 1/12/01)
2. GZA Weir River study
3. Samantha Woods, Weir River Watershed Association. Personal communication, June 2002.
4. Hutchins, Eric. National Oceanic and Atmospheric Administration. Personal communication, March 2, 2004 and Brad Chase MA Division of Marine Fisheries. Personal communication, March 2004.

Causes and Effects

Groundwater Withdrawals

What is Groundwater?

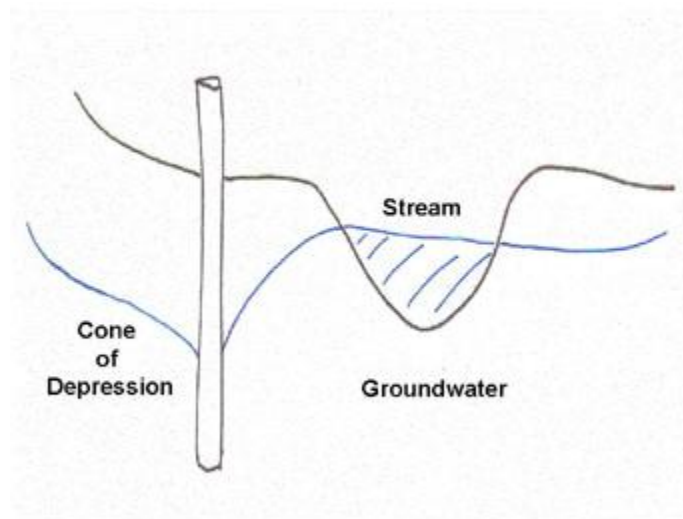
Groundwater is the water that is stored in the interstitial space, or space between particles, underground. Some soil materials have the ability to store more water in their interstitial space than others. As a general rule, materials made of large particles like sand and gravel (below, left) have more interstitial space than soils made of smaller particles like silt and clay (below, right) because they cannot be packed together as tightly.



What Happens When Groundwater is Pumped?

Regardless of the type of aquifer in which a well is located, groundwater responds to pumping in two ways:

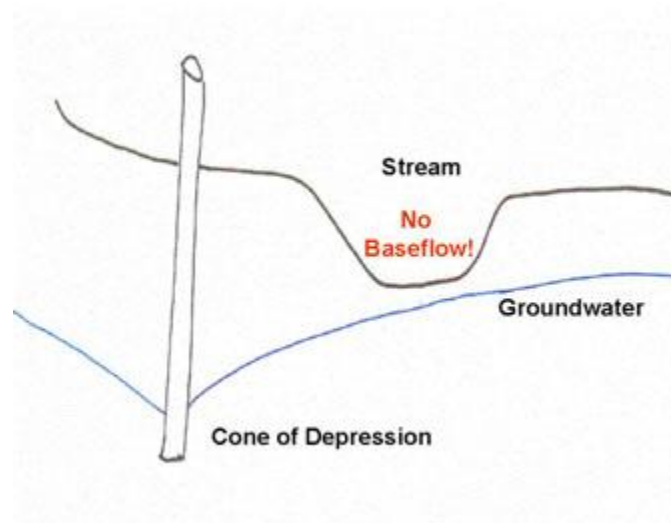
1. The level of groundwater, or water table, is lowered and a cone-shaped depression on the surface of the water table is formed near the well.
2. Water from other areas rushes toward the well to replace the water that is removed. This phenomenon is called recharge and occurs where there is no barrier to water movement.



In most cases, both effects are observed. Initial pumping causes the water table near the well to drop and forms a cone-shaped depression on the surface of the water table (see figure above). As pumping continues and more water is removed, the cone expands, but at an ever-slower rate because the expansion of a large cone of depression requires more water to be withdrawn than a smaller one.

How do Groundwater Withdrawals Affect Streamflow?

In some cases, as the cone of depression expands, it hits a recharge feature, or another source of water such as a river or lake. Continued pumping of the well may induce infiltration, or cause water to flow from the recharge feature into the ground and slow or halt the expansion of the cone of depression. If the stream is small relative to the amount of water being withdrawn, it may dry completely, especially during periods of naturally low flow (see figure below). If this happens, the cone of depression will extend beyond the recharge feature and continue to expand. On the other hand, if there is an impermeable layer, such as clay, on the lake or river bottom, there may be little interaction between groundwater and surface waters.



Structural Alterations

Streamflow in unaltered systems varies naturally during the course of the year. In fact, these pulses from high water to low water and back again, known as the natural flow regime, actually create the dynamic and interdependent habitats in and around flowing waters and fosters the biological life that flourishes in them. This natural flow regime refers to the magnitude, frequency, duration, rate of change and timing of streamflow that would have occurred without human modification of a river or its watershed characteristics.

In Massachusetts, spring is the time of high water, when melting winter snows and spring rains flood watersheds, streams and, ultimately, rivers. Low flows occur naturally in late summer and fall when plants are taking in a lot of water to support their full load of leaves. Native aquatic plants and animals have evolved to take advantage of a particular river's natural flow regime and frequently suffer when it is altered.

Effects on habitat

As streamflow decreases, many physical changes occur that can negatively impact aquatic habitats. First, water levels drop below the banks where overhanging roots and woody debris, during normal flows (below left), offer excellent habitat for many aquatic species, including fish, invertebrates, reptiles, and amphibians. The banks are then exposed (below right) to desiccation, wind, and freeze/thaw cycles, which can cause increased streambank erosion and sedimentation downstream. These processes reduce

the amount of stable bank habitat that is normally used by many invertebrates and semi-aquatic mammals—such as beavers, snakes, and otters—and smother gravel and cobble streambeds that are critical nesting habitats for fish.



As water levels recede further, riffles may dry out (below left), cutting off migration and movement routes for aquatic species as well as cutting off the flow of the river that some species require to survive or reproduce successfully. Riffles serve as some of the most productive areas for aquatic macroinvertebrates, such as mayflies and stoneflies, which are a major source of food for many fish.

In extreme cases, rivers may dry into a series of isolated pools (below right). Aquatic organisms are then concentrated into small spaces with little cover and increased predation risk.

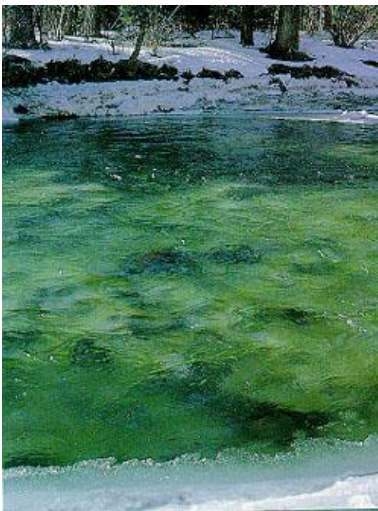


Effects on water quality

In addition to shrinking habitat and availability of cover, declining streamflow is associated with several water quality concerns. As water levels drop, streams and rivers become shallower, with less area shaded by riparian vegetation, and the waters generally experience a rise in temperature. This problem can exacerbate the naturally occurring summer conditions in Massachusetts—low flows and high temperatures. Declining groundwater levels can also cause cool springs and groundwater seeps to cease flowing, which further increases the temperature of many streams. Many species of fish require cool water temperatures even in summer, and they can be seriously stressed by high temperatures and loss of cool spring refugia.

Dissolved oxygen concentration is partially dependent on water temperatures and the amount of turbulence in rivers. Thus when temperatures increase and rivers slow or cease flowing completely, dissolved oxygen can fall to critical levels for many aquatic species. Low dissolved oxygen concentration is often blamed for extensive fish kills during extreme low water periods.

In streams and rivers with large loads of pollutants, low water levels can concentrate these pollutants and cause health concerns for aquatic species and humans alike. Low water levels also concentrate nutrients such as nitrogen and phosphorous which can lead to unpleasant algal blooms in many water bodies, as shown here.



In Massachusetts, most low flow concerns center on summer conditions because that is the time when streamflow is naturally lowest and human water use is highest. But low winter flows can also cause serious problems for many aquatic organisms. River banks and mud flats are the winter hiding places for many aquatic and semi-aquatic species that depend on a covering of water to protect them from freezing conditions. When these habitats are exposed to freezing temperatures and dry conditions, many species, including mussels, frogs and turtles, may experience increased overwinter mortality. In some smaller streams, low water levels may allow ice to form all the way down to the stream bed (as shown to the left), causing aquatic organisms to either move further downstream or be frozen solid.

Dams

Effects on streamflow

For thousands of years humans have built dams to control the flow of water. In Massachusetts, Native Americans built small dams, or weirs, to corral fish long before European settlers arrived. The colonists wasted no time in erecting dams to power grain and paper mills, and in the 19th century, textiles mills were constructed across the Commonwealth as part of the Industrial Revolution. Today, Massachusetts has an estimated 3000 dams over 6 feet tall and numerous, though uncounted, smaller structures blocking streamflow on its rivers and streams. This legacy of streamflow manipulation has left its mark on our



aquatic resources by changing the natural flow regime in many rivers. Depending on the details of a particular dam and its management, changes in the natural flow regime can lead to changes in water quality, habitat condition, and aquatic plant and animal life.

Effects on water quality

As water is held behind a dam the surface layer is warmed by the sun and sediments and organic particles that were suspended in the water column settle out on the stream bottom. In the bottom layers, this organic muck decomposes, consuming oxygen in the process, and can lead to anaerobic conditions in the deeper areas behind many dams. In addition to oxygen problems, the sediments that settle out can literally fill up the entire area behind a dam in a matter of mere decades, in some cases.

Water that is released over the dam from the surface layers will often raise the temperature of the stream below the dam, which can cause added stress to downstream aquatic life that may depend on cool water temperatures. Water released from the lower layers can actually cause fish (and other organism) kills if it is severely oxygen depleted.

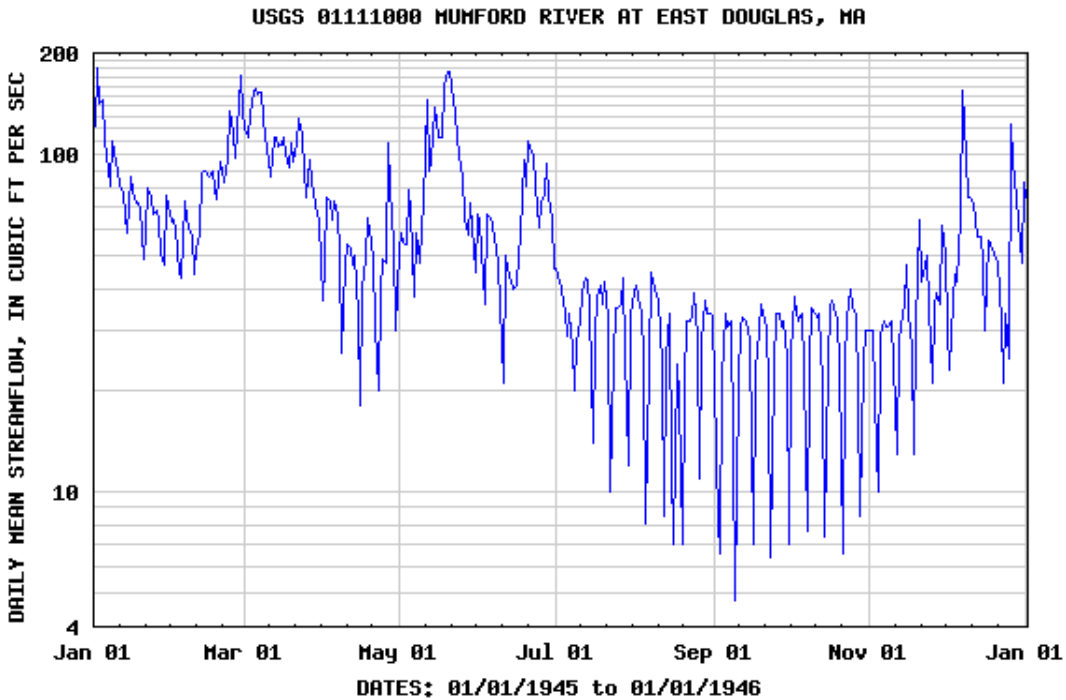


Effects on habitat

The most obvious change in aquatic habitat quality caused by dams is the conversion of flowing water to standing water. Many native river organisms are in some way specialized to depend on flowing water conditions and cannot survive in standing water conditions (see Aquatic Life below). In addition, the physical structure of the dam itself prevents most aquatic organisms from moving freely up and down the river. Even when fish ladders are installed, many organisms are not able to navigate the passage and are trapped in a single stretch of river. For organisms with large home ranges or migratory needs for feeding or reproduction, barriers to movement are substantial obstacles to successful reproduction.

Changes in the amount of water and suspended material cause changes in the physical shape of aquatic habitat both near dams and farther downstream. For example, water that is released out of a dam typically scours new areas and causes unstable banks just downstream. As sediment is eroded from the unstable banks or scoured from the streambed itself, it is carried far downstream, where it is deposited in new areas and may smother eggs or benthic invertebrates.

Dams can also cause changes in the rate of water level fluctuation in a river. Some hydropower dams operate in “hydropeaking” mode to provide energy when it is most needed. Water is held behind the dam during hours when energy demand is low and released only when energy demand is high. While this may sound like an intelligent way to provide energy on demand, it means that the river downstream of the dam is exposed to near-dry conditions while water is filling up behind a dam, followed by large surges of water released to produce energy. These fluctuations can occur several times a day below some hydropower dams. The graph below shows the effects of a hydropeaking dam on the Mumford River at East Douglas . Notice how streamflow declined as water was stored behind the dam (falling limb of each peak) and streamflow increased as water was released over the dam to generate power (rising limb of each peak), particularly from July through November.



Effects on aquatic life

All of these changes to streamflow, water quality, and habitat cause added stress to plants and animals that are adapted to the natural flow regime. In some cases, organisms can simply shift to a new, more suitable habitat, such as the migration of riparian plant species further down the streambank when chronic low flows occur. Some organisms, such as many benthic invertebrates, simply cannot maintain their position in the stream in rapidly fluctuating water levels and are carried downstream. In other cases, adult organisms can survive the changes in their environment, but they cannot reproduce successfully. For example, trout require clean, well-oxygenated, shallow gravel areas to successfully lay and hatch their eggs. In rapidly fluctuating water levels, low dissolved oxygen conditions, or turbid water full of sediment from eroding banks, these eggs will never hatch. Still other situations can cause changes in growth patterns, particularly in juveniles.

Finally, all of these responses to changes in the natural flow regime can eventually lead to changes in the structure of the aquatic community. River specialist species are replaced and out-competed by habitat generalist species, which can thrive in a wider range of environments. Dams also cause populations of species to be isolated from one another. This change in community structure can lead to local extirpations of some river-dependent species because the isolated areas can no longer be repopulated from individuals travelling up or downstream.



Habitat specialists, like the Baetis mayfly (left) depend on flowing water to survive. Habitat dependents, like the white sucker (center) can survive in ponded conditions, but cannot successfully reproduce without flowing water. Macrohabitat generalists, like the green frog (right), can survive and reproduce in both flowing and ponded habitats.

Permitting & regulations

Hydropower dams are licensed by the Federal Energy Regulatory Commission (FERC). For projects with a generating capacity of 5 megawatts or less, FERC will generally issue a waiver with conditions based on recommendations from state and federal agencies. Larger projects go through a permitting process yielding 30- to 40-year permits. Either of these processes can result in water management conditions to benefit, or at least reduce the negative impact to aquatic life.

For dams that do not generate power it is more difficult to impose streamflow requirements. Projects that involve withdrawing water from the stream may need to file a Water Management and/or Interbasin Transfer permit, either of which could theoretically be used to impose flow management conditions. However, this has rarely occurred in Massachusetts, and most small dams do not have legal flow requirements.

Ecological Alterations



Along with the [structural alterations](#) when streamflow is restricted come changes in the habitat and the ecological communities of riverine systems. If streamflow is altered for long periods, brings wide swings in flows, or recurs more often than normal, profound and long-lasting changes to the ecological integrity of the natural communities can be devastating.

Habitat & the Physical Environment

Physically, a severe reduction in streamflow contributes to decreased oxygen levels, increased water temperatures, and

concentrated pollutants. It also restricts navigation for both aquatic organisms and humans when pools become isolated from each other. Stagnant conditions increase the likelihood of algal blooms and contribute to the desiccation of streamside and wetland habitat and vegetation as the water's edge recedes from the bank.

The amount and distribution of shallow, vegetated, deepwater, and other habitat types also changes when the river recedes from the streambank. Fish, freshwater mussels and other water-dependent organisms can suffocate when oxygen levels get too low, even if the stream still has some water in it. Fish species that prefer cold water, like trout and salmon, may not be able to survive when the cool, deep springs they depend on during warm summers become shallow and warm or stop flowing altogether.

Changes in the natural flow regime can also cause streambank instability. Banks that are normally covered with water become unstable when they are exposed to desiccation, wind, or freeze and thaw cycles. When water returns in the form of surface runoff or increased flow, these banks have a higher likelihood of eroding and causing sedimentation problems downstream.

Vegetation

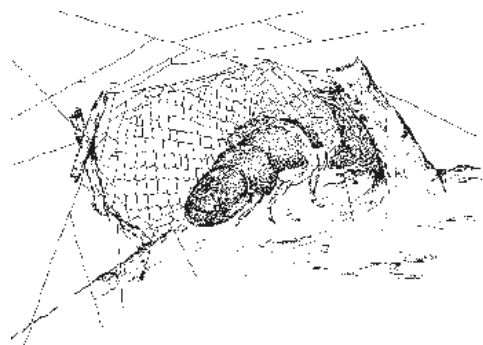
Extreme low flows and rapidly fluctuating streamflow conditions can cause changes in riparian and aquatic vegetation. Many riparian species are adapted to the naturally occurring cycles of wet and dry periods and cannot reproduce successfully if conditions are not right for germination or seed dispersal, for example. Additionally, altered flow regimes often favor invasive exotic species that can survive under less variable and lower flow conditions. In many rivers with low flow problems, purple loosestrife is one common invader that displaces native vegetation but does not serve the same ecological functions.

Flowing Water Adaptations

Many riverine aquatic organisms depend on continuously flowing water for some part of their life cycle. For species that depend on flowing water, a year with no flow means a year with no reproduction. For short-lived species, several years of extreme conditions can seriously reduce the size of the population and its ability to repopulate the river when sufficient streamflows return.



For example, trout lay their eggs in a nest (redd)



over clean gravel and even fan the redd with their tails to keep it free of sediment and well-oxygenated. Without enough flow to help them keep sediment from settling on the eggs and enough oxygen in the water, these eggs will die.

Some freshwater mussels release their eggs (glochidia) in a fish-shaped lure that they suspend in the water column. Fish then eat the lure and the eggs attach to the fish's gills to complete the next part of their life cycle. Without enough

flow in the river to support the lure in the water column, the fish won't eat the lure and the eggs can't attach to the fish's gills.

Net-spinning caddisfly larvae spin a web to collect their food from the water column. Without enough flow to support their nets these caddisfly larvae have no source of food.

Community Structure

A lack of flowing water wreaks havoc with the entire aquatic community. When river dependent species can't successfully reproduce or are driven out of a river because of poor habitat conditions, the fish and macroinvertebrate assemblages shift from being dominated by river-dependent species to being dominated by pond-like species. In the Ipswich River, which has serious summer low-flow problems,

95% of the fish are habitat generalists, or pond-like species, as opposed to only 55% generalists in the target, or ideal, Ipswich River fish community . Aquatic macroinvertebrate assemblages at sites with little to no flow are frequently dominated by midge larvae and have a reduced number of sensitive species such as mayflies, stoneflies, and caddisflies.

Estuaries

Seventy to ninety percent of the world's commercially important marine species depend on estuaries and their delicate balance of fresh and salt waters at some point during their lives. Forty percent of all continental runoff, or all the water that falls over land as precipitation and runs into rivers and ultimately estuaries, is intercepted by man-made reservoirs along the way. This means that there is currently seven times more water stored in rivers than there was before the era of large dam building. Controlling the amount of fresh water that reaches estuaries has a huge impact on estuarine habitats and the organisms that depend on them.

Salinity, or "saltiness", is often a major limiting factor for organisms that spend all or part of their lives in estuaries. Too much or too little salt can mean the difference between life and death for many organisms, particularly during their early life stages. Changes in river flow can alter the salinity in estuarine habitats and effectively isolate organisms from their preferred habitats such as sea grass beds, rocky



intertidal zones or salt marshes. River flow also controls the depth and temperature of many estuarine habitats. The photo to the right shows islands of clamshells in the Colorado River Delta, illustrating the 90% decline in clam abundance due to the lack of fresh water flow from the Colorado River.

Shifting salinity gradients can have different effects on estuarine organisms depending on where they live. Benthic organisms (those that live on the bottom of the estuary), such as clams, mud snails or the eggs of many species, generally move too slowly to adjust to changes in salinity and are often hit hardest by altered freshwater flows to estuaries. Organisms that move more readily will generally follow their preferred range of salinity around the estuary, but may have a smaller area of adequate habitat available to meet their needs for food or reproduction.

Over a period of several years, changes in the amount of freshwater flowing from a river into its estuary can cause shifts in the structure of the estuarine community. Much like the changes in community structure that occur in rivers with low stream flow problems, species that depend on freshwater or low salinity habitats in estuaries will tend to have less successful reproduction and higher mortality as river flows decline and will gradually be replaced by species that prefer saltier water. This can often give non-native generalist species an advantage over native species that are adapted to the historic conditions in a particular estuary.

Measurement Methods

Currently there are no regulations for managing streamflow based on the biological needs of a river. However, there are a number of scientific methods available to determine how much water should be left in a river to support a healthy river community. Each method makes different assumptions about what is most important to aquatic communities. A few of the most common methods are:

Range of Variability (RVA)

This method was developed by the Nature Conservancy in response to the growing concern that natural variability and not just minimum streamflows are required to support healthy aquatic communities. Using RVA, 33 statistical aspects of streamflow are compiled and target streamflows are suggested to fall within one standard deviation of the mean values. For example, the duration of low flow periods should fall within one standard deviation of the historic duration of low flow periods.

Mesohabitat Simulation Model (MesoHABSIM)

Currently under development at the University of Massachusetts, Amherst, MesoHABSIM is based on the IFIM concept of habitat modeling (*see below*), but focuses on larger reaches, or "meso-habitats" such as riffles, runs and pools. Physical characteristics of each mesohabitat are measured and compared to fish habitat preferences to determine the amount of useable fish habitat at different water levels. MesoHABSIM is currently being refined on several watershed-scale assessment projects.

Instream Flow Incremental Methodology (IFIM)

IFIM was developed by the USGS as a way to quantify and manage the effects of streamflow on fish. First, a target fish species or several key species are identified. Next, a study of the types of habitat occupied by each life stage of each species is conducted in the river. Then, a relationship between different streamflows and the availability of each type of habitat is determined. Minimum flow recommendations are developed by weighing the amount of habitat available for each species and life stage at low flows.

New England Aquatic Baseflow (ABF)

This method was developed as an interim policy for minimum streamflows in New England by the US Fish and Wildlife Service. The August median flow is suggested as a minimum summer flow value because it represents the most severe naturally occurring condition that a stream community would experience. For ungaged streams, where the August median flow is unknown, a summer default value of 0.5 cubic feet per second per square mile of drainage area (cfs/m) is suggested based on a survey of minimally impacted reference streams and rivers in New England. Because higher flows are needed at other times of the year for spawning, migration and other biological needs, USFWS's minimum flow recommendation for fall is 1.0 cfs/m and for winter and spring is 4.0 cfs/m. Where a minimum of 25 years of data is available, monthly median flows are suggested.

R2Cross

A combination of wetted perimeter (*see below*), depth and water velocity is used to describe the minimum flow necessary to maintain acceptable habitat for fish and macroinvertebrates in critical areas

such as riffles. By maintaining habitat in these critical areas, the model assumes that other habitats, such as pools and runs, will also be maintained.

Wetted Perimeter

The wetted perimeter (the submerged stream width) in riffles is used as an index of fish food availability. It is assumed that by maximizing the wetted perimeter of riffles, enough fish food and habitat will be available to support a healthy aquatic community in the river as a whole. The minimum streamflow required for habitat protection is the one where increases in streamflow no longer produce large increases in wetted perimeter. This point usually occurs when water covers the streambed to the bottom of the bank.

7Q10

The 7Q10 refers to the lowest consecutive seven-day streamflow that is likely to occur in a ten-year period. It is used by many states and the federal government in setting discharge limits in National Pollutant Discharge Elimination System (NPDES) water quality permits. A permit will only be granted if the proposed amount of pollutant that will be discharged into a river will not significantly impair the designated uses, such as drinking or swimming, when the streamflow falls to the 7Q10 level. In other words, NPDES permit holders are restricted from discharging pollutants that would cause pollutant concentrations in the receiving water to exceed permit limits, even at very low (i.e., 7Q10) streamflow levels. Although such a low streamflow value, roughly equivalent to a ten-year drought, is appropriately used in the context of limiting pollution discharges, the 7Q10 flow statistic is sometimes inappropriately claimed to represent an adequate streamflow for maintaining a healthy aquatic ecosystem, when in fact much higher streamflow levels are required.

Glossary

Aquifer. An underground geologic formation capable of holding large quantities of water in the (interstitial) spaces between rocks, sand, and soil. Aquifers may serve as a source of drinking water.

Aquifer transmissivity . The quantity of water that a given aquifer can transmit. It is calculated as the average hydraulic conductivity times the average thickness of the aquifer.

Base flow. The flow that a perennially flowing stream reduces to during the dry season. It is supported by groundwater seepage into the channel.

Benthic. Pertaining to the bottom (bed) of a water body.

Biomonitoring. Examining the biological (living) communities in a given body of water (or other habitat) to determine the complexity, diversity, and species composition in the water body. This information helps assess the overall health of the habitat.

Cfs. Cubic feet per second. A unit expressing rates of discharge. One cubic foot per second is equal to the discharge of a stream of rectangular cross section, 1 foot wide, and 1 foot deep, flowing water an average velocity of 1 foot per second.

Cfsm. Cubic feet per second per square mile. The average number of cubic feet of water per second flowing from each square mile of area drained by a stream, assuming that the runoff is distributed uniformly in time and area.

Class A, B, C water quality standards. Under the Federal Clean Water Act, each state must establish specific water quality classifications with defined water quality criteria. In Massachusetts waters are assigned an A, B, or C classification. A waterway's classification reflects the water quality needed for the designated uses of a given water body (the waterway's potential) and not the existing water quality.

Clean Water Act. A federal law establishing comprehensive national policies for water quality management. The essence of the CWA is to have all US waters "fishable and swim able".

Discharge. The rate of flow, especially fluid flow; the volume of fluid passing a point per unit time, commonly expressed as cubic feet per second, million gallons per day, gallons per minute, or cubic meters per second.

FERC. The Federal Energy Regulatory Commission is an independent regulatory agency within the Department of Energy that, among other energy-related tasks, licenses and inspects private, municipal and state hydroelectric projects.

First order stream – The smallest size class of streams (i.e. a "headwater stream"). Where two first order streams join the resulting stream is considered as second order.

Groundwater. Water that is held in the rocks and soil beneath the surface of the earth. Ground water feeds wells and springs.

Impervious Surface. A surface that does not allow water to penetrate such as pavement.

Impoundment. A body of water contained by a barrier such as a dam.

Induced infiltration. Movement of water from a surface water feature, such as a river or lake, into the groundwater as a result of groundwater pumping.

Inflow (to a reservoir). The amount of water flowing into a reservoir from upstream tributaries.

Interbasin transfer. A transfer of water from one basin (watershed) into another. These transfers are regulated in Massachusetts under the Interbasin Transfer Act.

Macroinvertebrate. Macroinvertebrates are small, but visible with the naked eye, animals without backbones (e.g., insects, worms, larvae). Water bodies have communities of aquatic macroinvertebrates. The species composition, species diversity and abundance of the macroinvertebrates in a given water body can provide valuable information on the relative health and water quality of a waterway.

Natural flow regime. The magnitude, frequency, timing, duration, and rate of change of stream flow in a particular river under “natural” conditions.

Percolation. Movement of water from the surface or surface groundwater into the groundwater table.

Permitted withdrawal. The amount of water that is permitted to be withdrawn at one location under the Massachusetts Water Management Act.

Pump test. A preliminary period of groundwater pumping to determine the capacity and environmental effects of a well.

Registered withdrawal. The amount of water that a given source was withdrawing at the time of the first passage of the Massachusetts Water Management Act. These withdrawals were allowed to be registered, or “grandfathered”, without having to complete the permitting procedure that is now required under the Water Management Act.

Rheophilic. Species that prefer or depend on flowing water conditions.

Riparian zone. The land adjacent to and along a river or stream. When a riparian area has a natural vegetative cover it serves a buffer between the upland and water course.

Run-of-river dam. A hydroelectric generating power plant that operates based only on available streamflow and some short-term storage (hourly, daily, or weekly).

7Q10. The lowest streamflow for seven consecutive days that occurs on average once every 10 years.

Species richness. The number of different species in a given area. The greater the number, the richer the area.

Stratified drift. Well sorted fluvial sands and gravels deposited from glacial meltwater streams. The permeability of stratified drift is greater than that of till.

Stream reach. A length of stream or river channel that is uniform in its discharge, depth, area, and slope; a relatively homogeneous length of stream having a similar sequence of characteristics.

Stressed basin. A designation created by the MA Office of Water Resources to aid in the implementation of the Water Management Act. Rivers in the “high stress” category have low streamflow for their drainage area as compared to other rivers of the Commonwealth of Massachusetts. Projects within these watersheds that may impact water availability are scrutinized more closely than in other areas.

Substrate. The base or surface on which an organism lives. This includes the material comprising a stream bed or the surfaces which plants or animals may attach or live upon.

Target fish community. The number and relative abundance of fish species that have been identified through expert opinion and historic data as a goal for fisheries restoration in a particular river.

Till. Unsorted and unstratified materials ranging in size from clay to large boulders that were transported and spread over the land surface by glaciers.

Turbidity. An optical property of water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample, i.e., the cloudiness or transparency of the water sample.

Watershed. The area of land drained by a river or stream system.

Definitions derived from:

- American Public Health Association
- Merriam-Webster dictionary
- Nevada Division of Water Planning Water Words Dictionary
- Sam Houston State University Hydrogeology online lecture notes
- South African River Health Program webpage
- USGS online glossary
- USGS Water-Resource Investigations Report 00-4029

Resources

Note, the online Low Flow Database had a series of online resources, but in our 2012 review we found that many links were broken. Rather than providing the links here, where they will eventually be obsolete, we list the topics of those resources which seem to still be current and assume that you can quickly find them using an online search engine.

- Massachusetts Department of Environmental Protection, resources include:
 - Tips and resources for water conservation
 - Drought advisories and water use restrictions
 - Water Management Act
 - Rivers Protection Act
- Massachusetts Water Resources Commission, resources include:
 - Water Conservation Standards
 - Guide to Lawn and Landscape Water Conservation
 - Interbasin Transfer Act
- Acton Water Department's water conservation tips
- New England Water Works Association's water conservation tips
- New England Wildflower Society's native plant nursery catalog
- New Hampshire Department of Environmental Services' water conservation website
- US Geological Survey
 - Real-time streamflow data for Massachusetts
 - Water resources investigation reports
- U.S. Environmental Protection Agency, resources include:
 - "Cases in Conservation: How efficiency programs help water utilities save water and avoid costs"
 - "Cleaner water through conservation"
- Water Use It Wisely campaign (national)
- California Urban Water Conservation Council
- Natural Resource Defense Council's case studies on stormwater strategies for the Northeast
- The Stormwater Manager's Resource Center
- American Fisheries Society, see "Effects of altered stream flows on fishery resources"
- American Rivers, resources include:
 - Report on the importance of instream flow
 - Instream Flow Toolkit
- The Instream Flow Council (national)